Success with Unrooted Cuttings From the Box to the Rooted Liner

Roberto Lopez, PhD
Department of Horticulture
Michigan State University

Jason Twaddell
Ball Horticultural Co.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

NORTHEAST GREENHOUSE CONFERENCE AND EXPO 2023

5 Stages for Cutting Propagation Success

Stages

0 Prior to arrival

1 Arrival, handling, and sticking

2 Callusing

3 Root development

4 Toning

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Essential Factors to Consider Before Sticking the Cuttings

- Planning and preparing
- Handling and storing URC correctly
- Prioritize sensitive crops
- Sort and group cuttings for success
- Sanitation considerations

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

PLANNING AND PREPARING FOR YOUR CUTTINGS TO ARRIVE

Your Goal:

Shorten the time from the box to the bench

Create a weekly checklist:

- ✓ Day(s) of arrival and # of cuttings?
- ✓ Who is the carrier?
- ✓ Prop house ready?
- ✓ Sanitation
- ✓ Labor?
- ✓ Trays and substrate?
- ✓ Cooler?

BMP For Storing Cuttings
Cooler Environment

- Your goal is to maintain the cold chain until the cuttings enter the Manufacturing Process.
- **Consistent Temperature Control**
  - Make sure the cooler is at the correct temperature the day before the cuttings arrive.
  - Temperature swings will minimize storage life and decrease performance after stick.

BMP For Storing Cuttings Cooler Environment

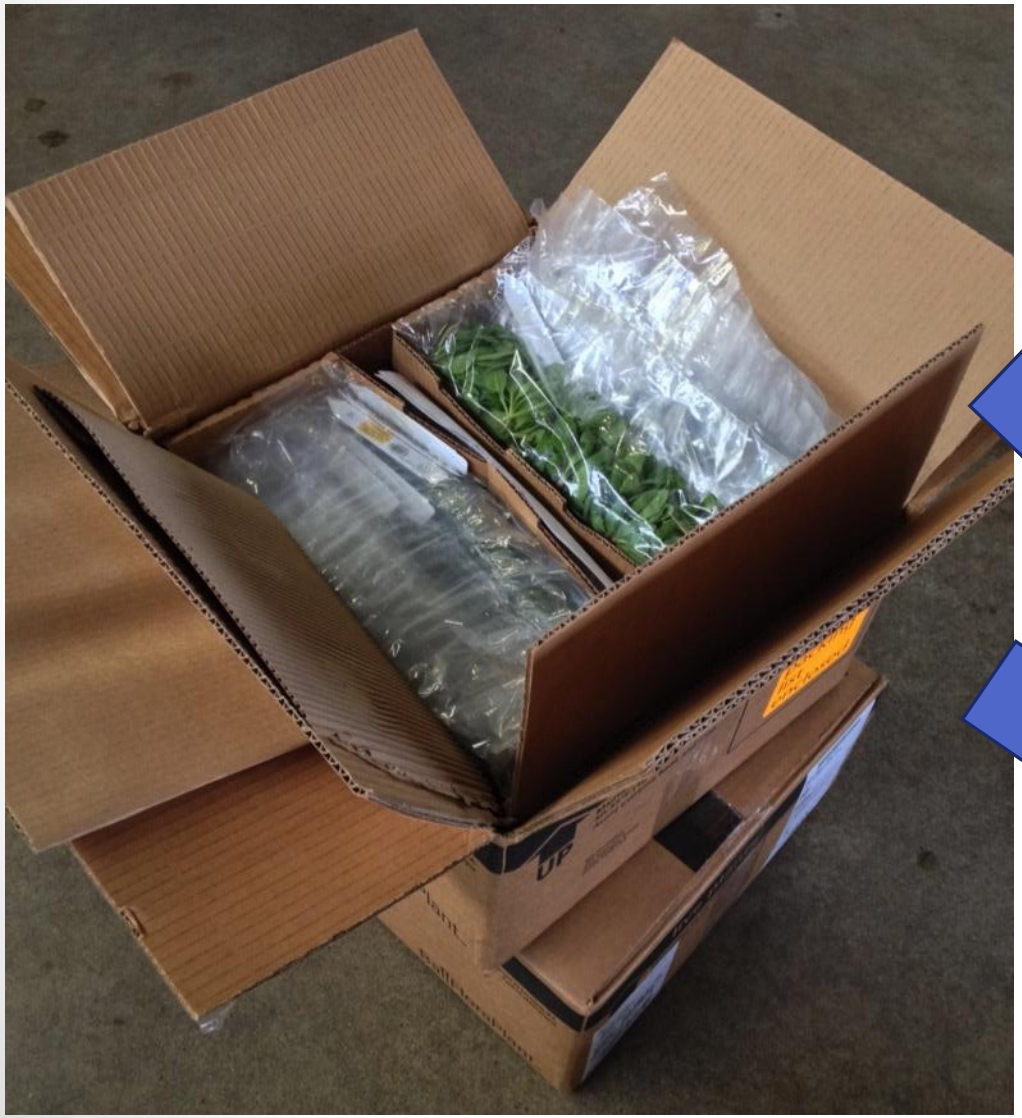
- Your goal is to maintain the cold chain until the cuttings enter the Manufacturing Process.
- **High humidity**
  - A cold but dry cooler is not a good storage environment.
  - Use fog, wet the floor and maintain humidity above 85%.

Sanitation Starts Now

- **Sanitation protocols starts before cutting arrival**
  - Cooler is clean, free of debris and sanitized.
  - Benches, carts, and trays used for sorting are cleaned and sanitized on a daily basis.
  - Plenty of gloves and spray bottles with sanitizer are available for workers that receive and sort cuttings.

START CLEAN – STAY CLEAN

What to do when cuttings Arrive?



DO NOT LEAVE CUTTINGS IN THE GREENHOUSE!!

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

STORING YOUR URC
COOLER SETTINGS

Cold Storage Crops 45 to 50 °F	
Argyranthemum	Geraniums
Bacopa	Lobelia
Bidens	Nemesia
Brachyscome	Osteospermum
Bracteantha	Petunia
Calibrachoa	Plectranthus
Cuphea	Salvia
Diascia	Scaevola
Dianthus	Verbena

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Storing your URC
Cooler settings

Warmer Storage Crops 50 to 55 °F	
Alternanthera	Lobelia
Angelonia	Impatiens, Double
Begonia	Impatiens, NG
Coleus	Impatiens, Interspecific
Dahlia	Poinsettia
Erysimum	Perilla
Euphorbia	Thunbergia
Heliotrope	Strobilanthes
Iresine	

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Cooler Storage > 48°F

New Guinea Impatiens, Impatiens, Lantana, Ipomoea, Vinca, Euphorbia, Dipladenia, Heliotrope

Cold Damage – New Guinea Impatiens

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Photo: Harvey Lang, Syngenta

Storing your URC
Cooler settings

Cold Sensitive Crops 55 to 60 °F Crops
Basil
Ipomoea (Sweet potato vine)
Purslane (Portulaca)

Photos: Jim Faust, Clemson Univ. and Harvey Lang, Syngenta

Prioritize and Sort URC for Success

When sorting your cuttings, use these steps:

1. Prioritize sensitive crops
2. Group by mist requirements
3. Group by rooting time

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Prioritize and Sort URC for Success…..Step #1

- **First priority** is to unpack & stick your cuttings based on the crop sensitivity:
  - Poor shippers
  - Highly temperature-sensitive
  - Sensitivity to ethylene
  - Difficult-to-root species or cultivars
  - Susceptibility to desiccation

Prioritize and Sort URC for Success…..Step #1

- **First priority** is to unpack & stick your cuttings based on the crop sensitivity

Ethylene and Storage Sensitive Crops	
Dahlia	Lantana
Geranium, ivy	Lobelia
Geranium, zonal	Purslane
Hybrid Euphorbia	Sweet potato
Heliotrope	Thunbergia

Damage Resulting from Warm Shipping Temperatures/ Ethylene

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

Photo: Jim Faust, Clemson Univ.

SECOND PRIORITY SPECIES

Stick day of arrival	
Agastache	Impatiens, Exotic
Artemesia	Impatiens, Mini
Bacopa	Lavender
Begonia	Lobularia
Coleus	Nemesia
Crossandra	Osteospermum
Diascia	Petunia
Erysimum	Wallflower
Evolvulus	Verbena
Fushia	Viola
Impatiens, Double	

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

THIRD PRIORITY SPECIES

Stick within 24 hours of arrival	
Multi liners	New Guinea Impatiens
Ageratum	Lamium
Alternanthera	Licorice plant
Angelonia	Lithodora
Argyranthemum	Mandevilla
Bidens	Garden phlox
Brachycome	Scaevola
Bracteantha	Strawflower
Cuphea	Torenia
Helichrysum	Yarrow
Impatiens, Interspecific	

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

FORTH PRIORITY SPECIES

Stick within 48 hours of arrival
Celosia
Gaura
Hedera
Lophospermum
Sanvitalia
Streptocarpella
Vinca major

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Sort and Group your URC for Success

1. **Crops with specific mist requirements should be grouped together in Stage 1 and 2**
   - Certain crops require more mist to remain turgid, especially in the first few days of propagation
   - Other crops need the opposite
   - Group these crops together to make life easier for the propagator…..**THIS ALL STARTS AT THE SORTING PHASE**
2. **Crops with similar rooting times should be grouped together**

Grouping by Mist Requirements

- There are at least 3 categories of mist requirements
- High mist crops, low mist crops, and the rest.

High Mist Group
Angelonia
Argyranthemum
Bracteantha
Celosia
Osteospermum
Scaevola

Low Mist Group
Evolvulus
Geraniums
Helichrysum
Portulaca
Sedum
Streptocarpella

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Grouping by Rooting Time

In general there are three groups

1. Fast rooting crops (5-7 days in Stages 1 and 2)
2. Moderate rooting (8-10 days in Stages 1 and 2)
   - This makes up the largest percentage of crops.
3. Slower rooting (10-14 days in Stages 1 and 2)

Build your own groups based on your facility and experiences.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Grouping by Rooting Time

After sorting and grouping by mist requirements, then group by rooting time.

How does this help?

- Allows larger blocks of trays with the same mist strategy including dropping the night mist, weaning mist or using the same VPD model.
- Increases efficiency of moving crews when time comes to change environment.

EXAMPLES OF ROOTING GROUPS

Fast Group	Moderate Group	Slow Group
Coleus	Petunia	Angelonia
Bounce Impatiens	NGI	Brachyschome
Sunpatiens	Lantana	Hedera
Double Impatiens	Helichrysum	Fuchsia
Lamium	Evolvulus	Calibrachoa
Plectranthus	Euphorbia	Scaevola
Iresine	Argyranthemum	Bracteantha
Bacopa	Guara	Osteospermum
Ipomoea	Lobelia	
Bidens	Salvia	
Cuphea	Thunbergia	
Verbena	Strobilanthes	

Ensuring a Good Start

Essential Factors

1. Uniform tray manufacturing
2. Proper substrate moisture before and after sticking
3. Dibble
5. Rooting hormones
6. Other chemicals

Manufacturing Process: Before you can grow a high quality liner, you have to manufacture the liner tray

- The Manufacturing process includes everything that occurs after the cuttings are unboxed and sorted (Material Handling Process) but before the liner tray has made it to the bench.

- This process normally occurs in a dedicated production area, at a sticking line or even on the growing bench.

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Manufacturing Process: Before you can grow a high quality liner, you have to manufacture the liner tray

- There are several essential factors required for a good start to liner production and these are as important as the cultural and growing protocols needed to finish a high-quality liner.

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Uniform Tray Manufacturing

- Growers can either purchase pre-filled trays from an outside manufacturer or prepare their own trays in-house.
- Firm, dense, and light weight
  - Support the cutting upright and without movement during rooting
  - Drainage and oxygen for rooting
    - Retain adequate moisture to keep the cutting turgid
    - 25 to 35% porosity
    - Substrate needs to be uniform in the tray

Uniform Tray Manufacturing

- Manufacturing your own trays gives you flexibility, security and control over the quality of the tray.
- Purchasing pre-filled trays can be a good option but it is important to hold tray manufacturers to a high standard so that your uniformity and quality standards are not compromised.

Essential Factor
Uniform Tray Manufacturing

- **Loose-filled trays:**
  - Filling all cells with the same volume of soil is the obvious goal
  - This includes uniform compaction
  - Build and maintain a tray filling protocol that includes proper tray weight and moisture after filling

Essential Factor
Uniform Tray Manufacturing

- **Rigid foams** (e.g., Oasis® Wedge or Root Cube)**:**

Essential Factor
Uniform Tray Manufacturing

- **Bonded/stable media solution** (ie. Ellepots™, Fertiss®, Preforma®, Jiffy®):
  - Should be manufactured with uniformity in mind
  - Different heights or levels of compaction can negatively impact the finished liner
  - Strict BMP for this process is essential

Essential Factor
Water Quality

- Water quality for misting, fogging, and irrigation
  - Electrical conductivity of water used for propagation should be <0.5 mS/cm
  - Water alkalinity should be <100 ppm bicarbonate
    - If high in bicarbonates, use acid to neutralize.
    - Nitric acid is best (but also dangerous); other acids work but leave residue on foliage

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Essential Factor
Water Quality

- Water quality for misting, fogging, and irrigation
  - High soluble salts can contribute to biofilm accumulation in the irrigation lines, which can block mist emitters
  - Use water that is low in salts, bicarbonates, sodium, and boron

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Essential Factor
Water Quality

- Water quality for misting, fogging, and irrigation
  - Use rainwater or RO water if water quality is poor

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Essential Factor
Ideal Substrate Moisture

- Level 4 soil moisture is ideal at the time of sticking the cuttings

- Too dry at the time of sticking will put undue stress on the cutting
- Too wet at the time of sticking will make it difficult to dry down the soil needed for root initiation

PROPER SUBSTRATE MOISTURE BEFORE AND AFTER STICKING THE CUTTING

- **Level 4 - Medium Wet**
- **Determine an ideal tray weight <u>before and after</u>** sticking, train staff to understand and implement this, then execute consistently.
- **Don't stick cuttings into dry substrates!!**

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Essential Factor
Dibble Correctly

Dibbling trays correctly can be a critical part of your Liner Manufacturing Process BMP

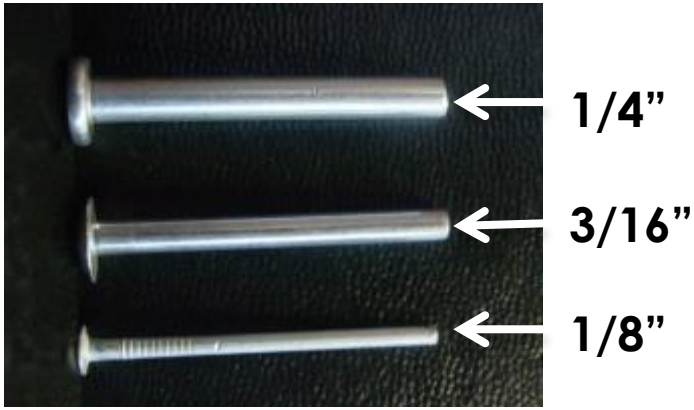
Quality Control

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

Dibble Correctly

Managing dibble size & depth



- Most dibble boards have adjustable stops that can help you to manage dibble depth.
- Develop a list of crops that have strict dibble requirements and train your staff.
- One size does not fit all crops so use a properly sized dibble pin.
- Ex. geranium or bracteantha requires a completely different dibble size than a lobelia or angelonia.

Sticking

- Typically, cuttings should be stuck ½ to ¾ inch (1.3 to 1.9 cm) deep into a rooting substrate.

- Cuttings that are stuck too shallow are prone to lodging, and cuttings stuck too deep may have root initiation and development hampered by lack of oxygen in space that is constantly filled with water.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Improper dibbling can lead to a lack of uniformity

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

ESSENTIAL FACTOR
ROOTING HORMONES

- 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
  - Can increase leaf yellowing by increasing the export of sugars from the leaves

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Essential Factor
Rooting Hormones

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

Rooting Hormone Beneficial	
Alternathera	Gazania
Angelonia	Geranium zonal
Argyranthemum	Helichrysum
Begonia hiemalis, reinger, rex	Leucanthemum
Bougainvillea	Lobularia
Bidens	Phlox paniculata and subulata
Campanula	Poinsettia
Cuphea	Torenia
Diascia	Veronica
Fuchsia	Viola

Essential Factor
Rooting Hormones

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

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

Rooting Hormone

Spray Application after sticking

- Can also be applied as a coarse spray over the crop that allows some of the solution to run down the stem toward the base of the cutting.
- The potassium-salt formulation of IBA is often used as it is water soluble, and therefore causes less foliar damage compared to alcohol-soluble formulations
  - 50 to 500 ppm IBA (@ day 1 or 2)
- Some leaf curl response can occur but the plants will normally grow out of it prior to shipping.

Floriculture
MICHIGAN STATE
UNIVERSITY

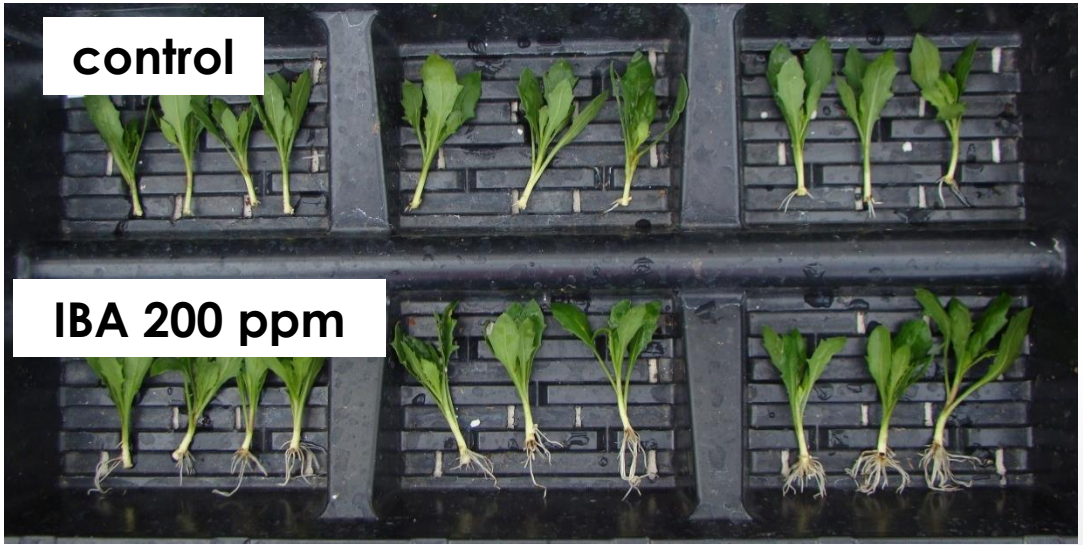
Ball FloraPlant.

ESSENTIAL FACTOR
ROOTING HORMONES

- Spray applications are generally more effective than basal dip cutting applications at promoting rooting of the four species we tested.

- Generally, a low volume spray application (2 qts. per 100 ft^2.) at 150 to 300 ppm was effective at promoting rooting of geranium, Dahlia, and Osteospermum.

Research



Ensuring a Good Start: Other considerations

Surfactants

- Use a nonionic surfactant like Capsil to help break the surface tension of the water on the leaf, re-hydrate leaves and reduce stress .
  - For Capsil use a 1-4oz/100 gallon rate as a foliar spray within 24 hours of sticking.
- This could be applied as the cuttings come off the sticking line, right after your water tunnel.

The problem: Lower-leaf senescence and abscission during propagation

28 d after treatment

BA + GA_{4+7} (ppm)

0 1 2 3 4

'Fantasia Purple Sizzle'

'Designer Salmon'

Research

Ensuring a Good Start: Other considerations

- Products containing BA + GA_{4+7} (Fascination or Fresco) are most likely the best for use in geranium propagation.
- Applying PGR solutions after stick were the most effective.
- BA + GA_{4+7} inhibited rooting, however dipping cuttings in a rooting hormone partially overcame that suppression.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

- Using PGRCALC, we estimated the PGR spray cost for a foliar application of solution containing 2.5 to 5 ppm BA + GA_{4+7} at a rate of 2 quarts per 100 ft^2 to be \$0.44 to \$0.88 per 1,000 ft^2 of bench space.

Research

Research

BY CHRIS CURREY, ROBERTO LOPEZ, VIJAY RAPAKA, JIM FAUST & ERIK RUNKLE

Keeping it Green

How to reduce lower-leaf yellowing of geranium cuttings in propagation.

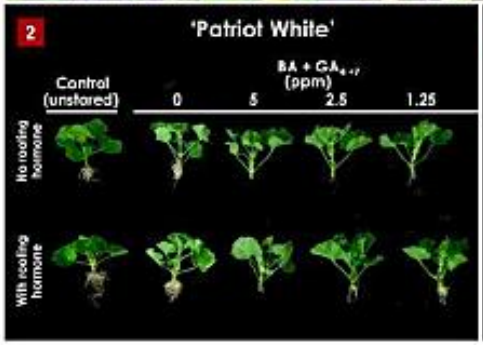
Unrooted geranium cuttings have a short post-harvest life and low tolerance to high temperatures during shipping. Undesirable shipping conditions can increase respiration (reducing carbohydrates) and increase ethylene generation in geranium cuttings, which can cause lower-leaf yellowing and senescence during propagation. Additionally, abscised leaves can host botrytis and cause losses during propagation. Therefore, fungicides are often applied during propagation and infected leaves are removed during production to reduce pathogen problems.

Applications of plant growth regulators (PGRs) such as benzyladenine (BA; a cytokinin) and/or gibberellic acid (GA) may suppress lower-leaf yellowing and senescence. Growers producing Easter lilies are already familiar with applying a BA and GA, known commercially as Fascination or Fresco, to keep the older, lower leaves green. In the past few years, some propagators of zonal geraniums have also been utilizing BA and GA during propagation to reduce lower-leaf yellowing of geranium cuttings. Our objectives were to: 1) determine if BA and/or GA should be applied either before or after shipping; 2) evaluate whether rooting hormones could overcome reduced rooting caused by the PGR applications; and 3) quantify the effects of BA + GA applications on several geranium cultivars. >>>

Figure 1. Geranium cuttings with lower-leaf yellowing are a common sight during propagation.

Figure 2. Patriot White geranium cuttings 20 days after being treated with 0 to 5 ppm BA + GA_{4+7} and rooting hormone (with or without) after a simulated shipping.

Figure 3. Fantasia Purple Sizzle and Designer Salmon geranium cuttings 28 days after being treated with 0 to 4 ppm BA + GA_{4+7}.



Most Common Mistakes When Starting Liner Trays

- ✓Poor uniformity in tray manufacturing
- ✓Improper substrate moisture before and after sticking
- ✓Dibble
- ✓Rooting hormone

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Grow a Better Liner

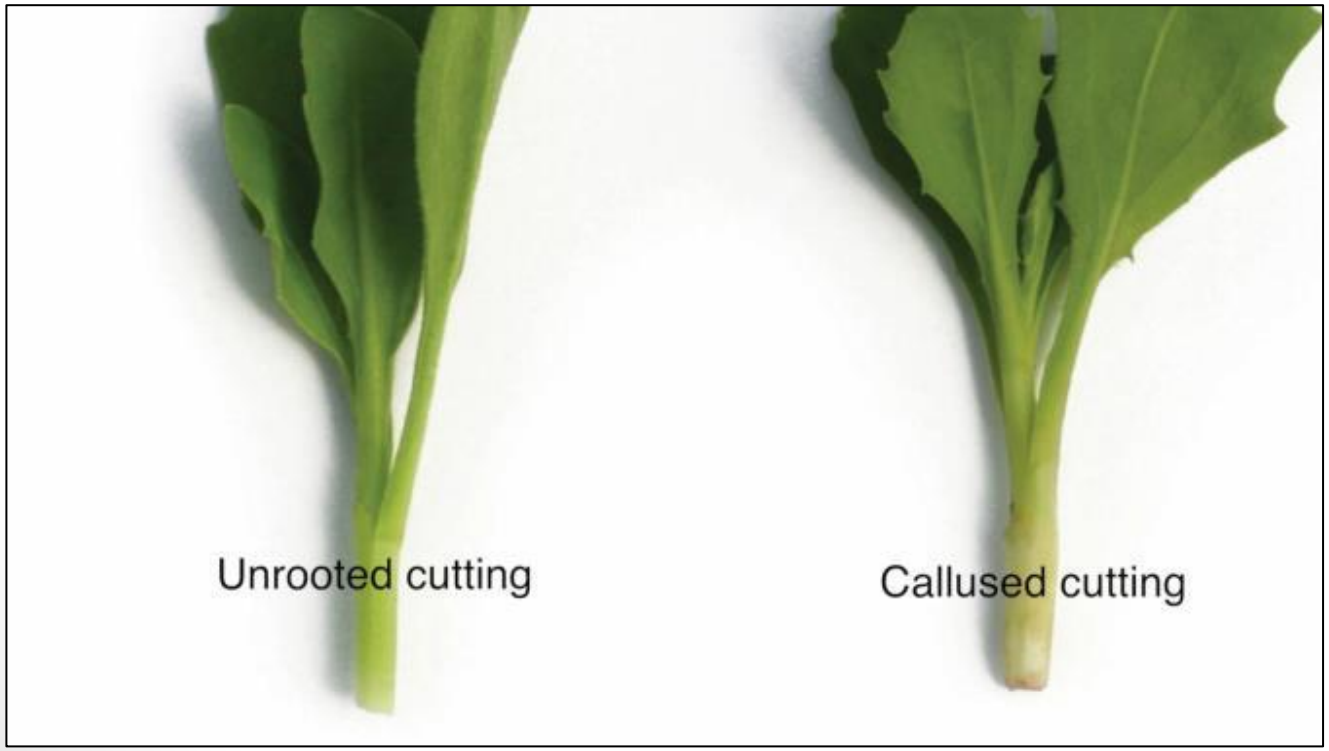
Cuttings are now in the Prop House!

Stages 1 – 4

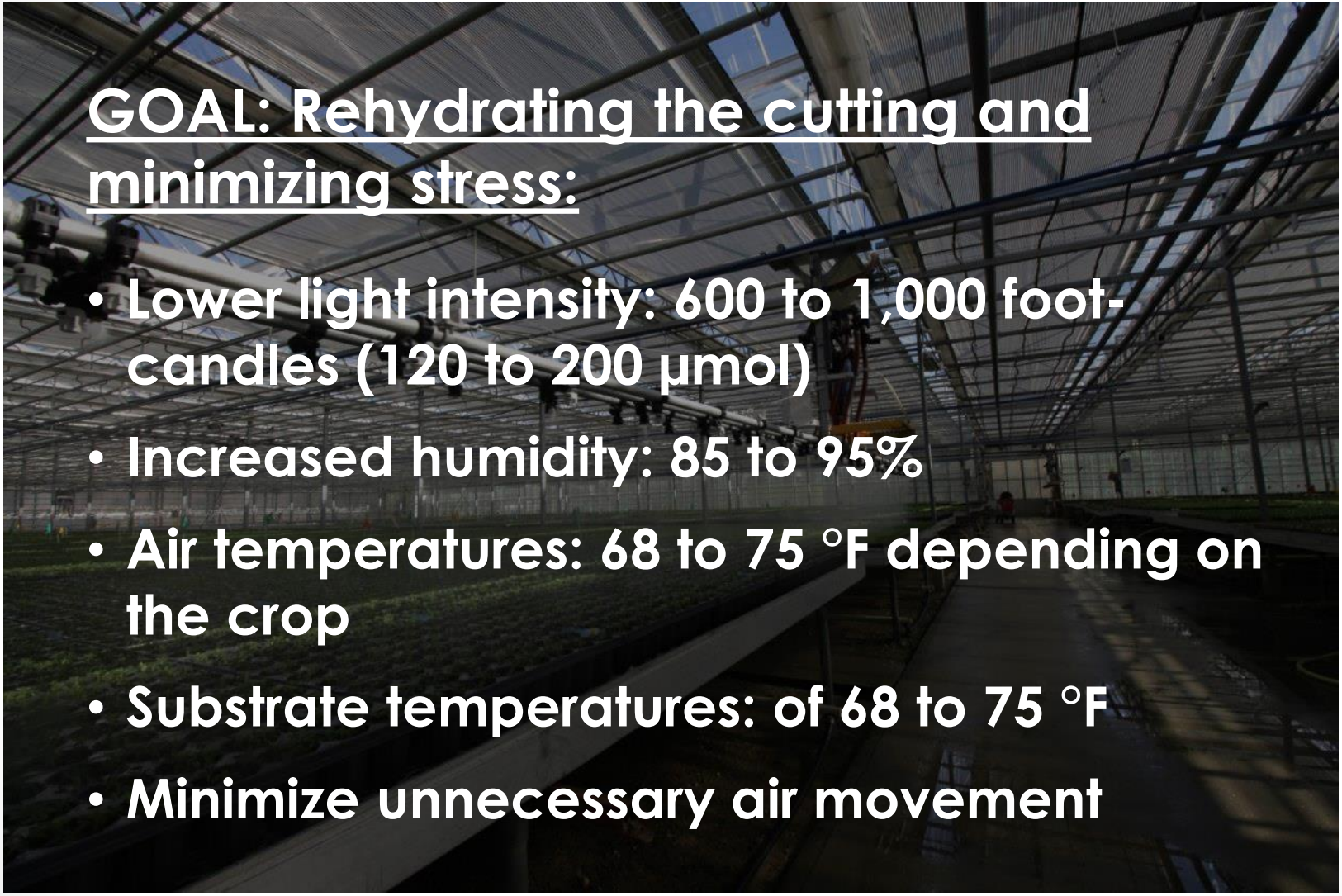
- Temperature/Humidity
- Light
- Moisture management
- Fertility
- PGR
- Pinching

Stage 1: Defined

- Stage 1 starts when the cuttings are first stuck and it ends when the cutting begins to form callus
- Can be anywhere from 3 to 8 days



Stage 1: Ideal Environment

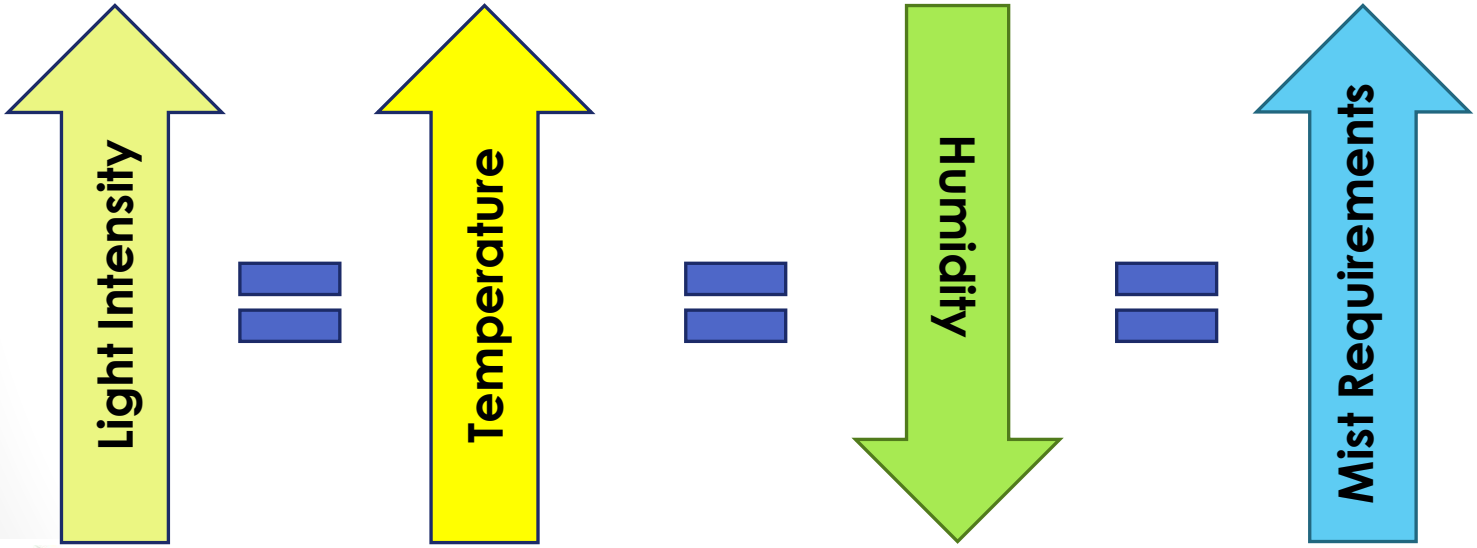


GOAL: Rehydrating the cutting and minimizing stress:

- Lower light intensity: 600 to 1,000 foot-candles (120 to 200 µmol)
- Increased humidity: 85 to 95%
- Air temperatures: 68 to 75 °F depending on the crop
- Substrate temperatures: of 68 to 75 °F
- Minimize unnecessary air movement

STAGE 1: FIND THE BALANCE

It is crucial that propagators find the balance between light levels, temperature, humidity and their mist strategy



Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

Stage 1: Find the balance

- Adjust your mist strategy as the environment changes.
- Increasing humidity is the goal to reduce the vapor pressure deficit.
- Mist should be applied to prevent cuttings stress:
  - Just barely coat leaf surface
  - Maintain 100% humidity
  - Supply little to no water to the substrate

Stage 1: Humidity Tents or Covers

- Typically used on begonias and other species that don't like free water on the foliage (Helichrysum, herbs, lobelia, etc.)
- Keeping cuttings "soft" with high humidity until good root formation (without over-saturation) is key

Stage 1: Temperature

Root-zone temperature is critical for callus induction and root initiation

- Hastens root initiation

Increasing substrate temperature:

- Hasten time to visible root formation
- Increase the number of roots per cutting

- **Above species-dependent T_o:**
  - Deleterious impact on rooting
- **Suboptimal temperatures:**
  - May inhibit or limit rooting

Stage 1: Temperature

- Stage 1: Bottom /root-zone heat is recommended for optimum rooting.
- With bottom heat, maintain media at 70 to 77 °F and air temperature at 65 to 73 °F.
- Without bottom heat, maintain air temperature at 75 to 78 °F.

Bottom heat

Bottom heat

Stage 1: Temperature

- The combination of cooler air and warmer substrate temperatures promotes rapid root initiation and growth without excessive shoot growth.
- Cool air temperatures also reduce the respiration rate of cuttings, which helps to reduce leaf yellowing during propagation.
- Additionally, water used for misting should be above 70 °F, as it can reduce substrate temperatures and delay callusing and rooting.

Stage 1: Root Zone Heating

Pipe under the bench is efficient, especially with fins

Stage 1: Bench Top Root Zone Heating

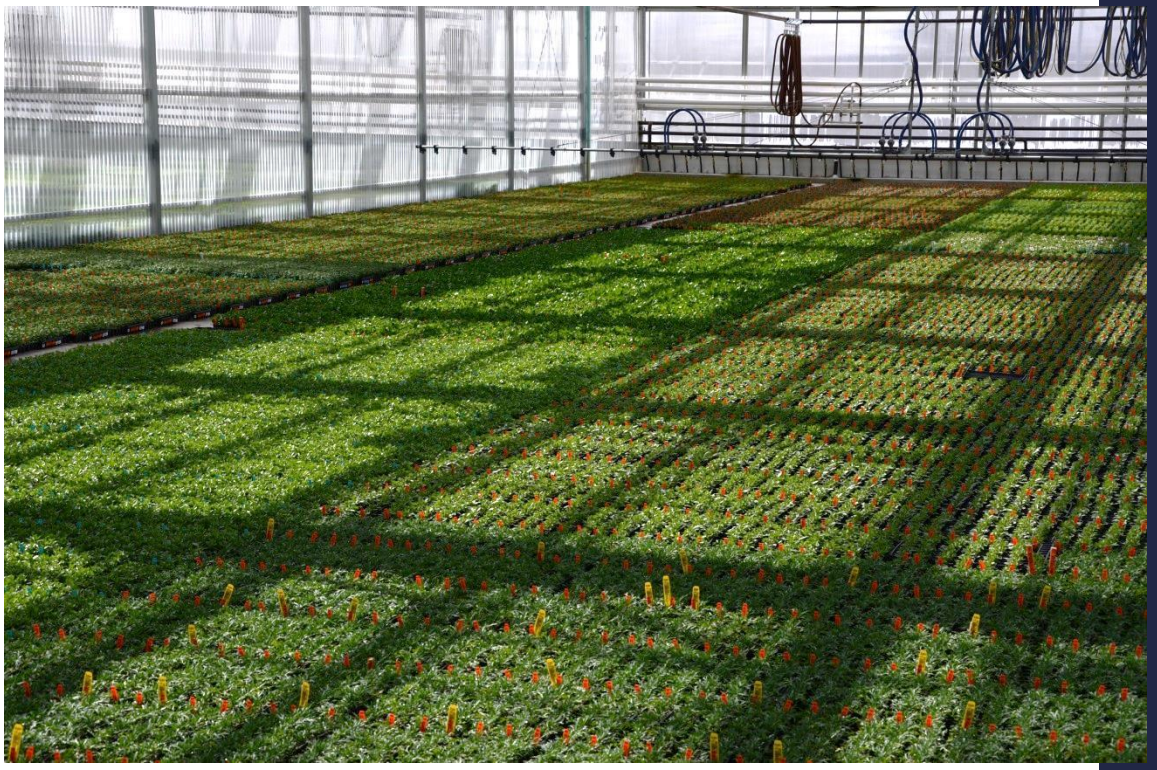
- Circulating hot water (120 to140 °F) under the plants. Originally buried in sand but that is not necessary.

- Also called "Biotherm", which is a trade name.

- Helps keep substrate warm and warms air around the plants. Especially useful in propagation.

Stage 1: In Floor Root-zone Heating

- Desirable for crops grown on the floor.
- Air temperature is generally lower so energy savings can be achieved.
- Overhead heating is still required.



CLOSELY MONITOR SUBSTRATE TEMPERATURE

Make sure you have the right tools to do the job

- Check your substrate temperatures daily to be sure that your heating system is working appropriately
- Just a few days of less the optimal temperatures will slow down callusing and rooting.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

G2 Bench 1

Bench Temp: (C) 21 (F) 70°

Date: 7/27/10

Initials: DV

Stage 1: Fertility

Foliar feeding

- Some growers have the ability to foliar feed their cuttings during Stage 1.
- Keep ppm N low, around 50 ppm.
- Low P fertilizers are common as foliar feeds.
- Biggest benefit from increased substrate EC.

EC at the end of Stage 1

- Ideally there is some EC at the end of Stage 1 so that nutrients are available as roots start to emerge.
- Find the balance between substrate moisture and fertilizing at the end of Stage 1.

Stage 1: Moisture Management

- Level 4 substrate moisture is ideal at the beginning and the end of Stage 1

- Too dry in the first few days of Stage 1 will cause unnecessary stress on the cutting.
- Too wet at the end of Stage 1 will make it difficult to dry down as needed for root initiation.
- Difficult balance which emphasized need for good mist strategy.

Biggest Mistakes Stage 1

- ✓Allowing cuttings to dry down excessively or wilt in the first few days
- ✓Not monitoring substrate temperatures
- ✓Incorrect environment to minimize stresses:
  - ✓Too much air movement
  - ✓Light intensity too high
  - ✓Low humidity
- ✓Overmisting after the first few days

STAGES 2

Stage 2: Defined

Stage 2 begins with a callused cutting

Stage 2 ends with roots to the edge of the cell

Stage 2: Callusing

Callused cuttings

Stage 2: Environmental Parameters

- Light intensity: more moderate light intensities >1000 and <2000 footcandles (>200 and <400 µmol)
  - DLI 3 to 5 $mol \cdot m^{-2} \cdot d^{-1}$
- With bottom heat, maintain substrate 70 to 77 °F and air temperature at 65 to 73 °F.
- Without bottom heat, maintain air temperature at 75 to 78 °F.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Stage 2: Environmental Parameters

- Diffuse, indirect light is best.
- White wash or exterior shade in combination with retractable shade curtains can provide a good system for light modulation, especially in the spring and summer.
- Retractable shade curtains alone can be the most effective way to modulate light transmission.
- Avoid excessive shading during winter months or during cloudy weather.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Light Modulation in a Propagation House

Stage 2: Mist Strategy

- Cuttings should be aggressively weaned off mist during this stage
- Night mist should turned off during Stage 2!!

Day(s)	12 to 7am	7 to 10 am	10 am to 5 pm	5 to 8 pm	8 to 12 pm
1-3 (Stage 1)	Mist	Mist	Mist	Mist	Mist
4-5 (Stage 1)	Mist off	Mist reduced	Mist	Mist	Mist reduced
6 (Stage 1)	Mist off	As needed	Mist	Mist reduced	Mist off
7 (Stage 2)	Mist off	As needed	Mist reduced	Mist reduced	Mist off
8 (Stage 2)	Mist off	As needed	Mist reduced	Mist off	Mist off
9 (Stage 2)	Mist off	Mist off	As needed	Mist off	Mist off
10 (Stage 2)	Mist off	Mist off	As needed	Mist off	Mist off

Stage 2: Mist Strategy

Problems associated with overmisting or not weaning cuttings off mist in Stage 2:

- Increased disease pressure, especially botrytis.
- Increased algae growth and fungus gnat and shore fly pressure.
- Reduced fertility in the cutting, as well as lower EC in the propagation media.
- Saturated soil that slows root initiation and rapid root growth and decreases uniformity of root initiation.

Stage 2: Moisture Management

Moisture Management

- Ideally the soil moisture is a level 4 during Stage 2.
- Level 5 (saturated) soil moisture will result in slower and less uniform rooting.
  - Lots of callus and not a lot of roots
- Level 3 (Medium) soil moisture is adequate but too dry can stall the root initiation process.

A good mist strategy is the is an essential part of providing the ideal soil moisture.

Overmisting = Saturated substrates

Stage 2 Fertility: Time to Recharge

Stage 2: Fertility

- Cutting nutrition has been decreasing since it was cut from the stock plant.
- Choose a balanced fertilizer with a low percent of ammoniacal nitrogen.
- 75 to100 ppm N is a good starting point with micros.

“Hungry” Petunias and Calibrachoas

- Keep feed levels up on these crops
- Consider boosting micronutrients in feed (1 ppm Fe, 0.5 ppm Mn)
- Supplemental drench of iron chelate (Sprint® fertilizer 138 or 330) at 2 oz/100 gal rate

Stage 2: PGR

- This is the first stage where propagators may start to use growth regulators.
- Vigorous crops may need to be toned before they have rooted.
- Especially important if you want to stack nodes for a crop that is normally pinched…example verbena.
- Utilize PGR with lower activity like daminozide or chloromequat to avoid over-regulation.

Stage 2: IPM

Stage 2: IPM

- Focus on controlling fungus gnats and shore flies.
- Preventative control measures are best for these pests.
- Good sanitation and cultural practices are key.

Biggest Mistakes of Stage 2

- ✓Overmisting
  - ✓Night mist should be off and day mist should be declining in frequency
- ✓Not starting to fertilize the crop
- ✓Saturated (Level 5) soil moisture leads to slow and uneven rooting
- ✓Neglecting IPM and disease control

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Stages 3 and 4

1. Change the environment
2. Build the root system
3. Bulk up the top
4. Pinching
5. PGR and controlled growth
6. Toning…..Stage 4

Stage 3

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Stage 3: Defined

Stage 3 begins with a rooted cutting

Change the Environment!!!

Stage 3 ends with a rooted liner

Stage 3: Ideal Environment

Active Environment

Light Levels
Fertility

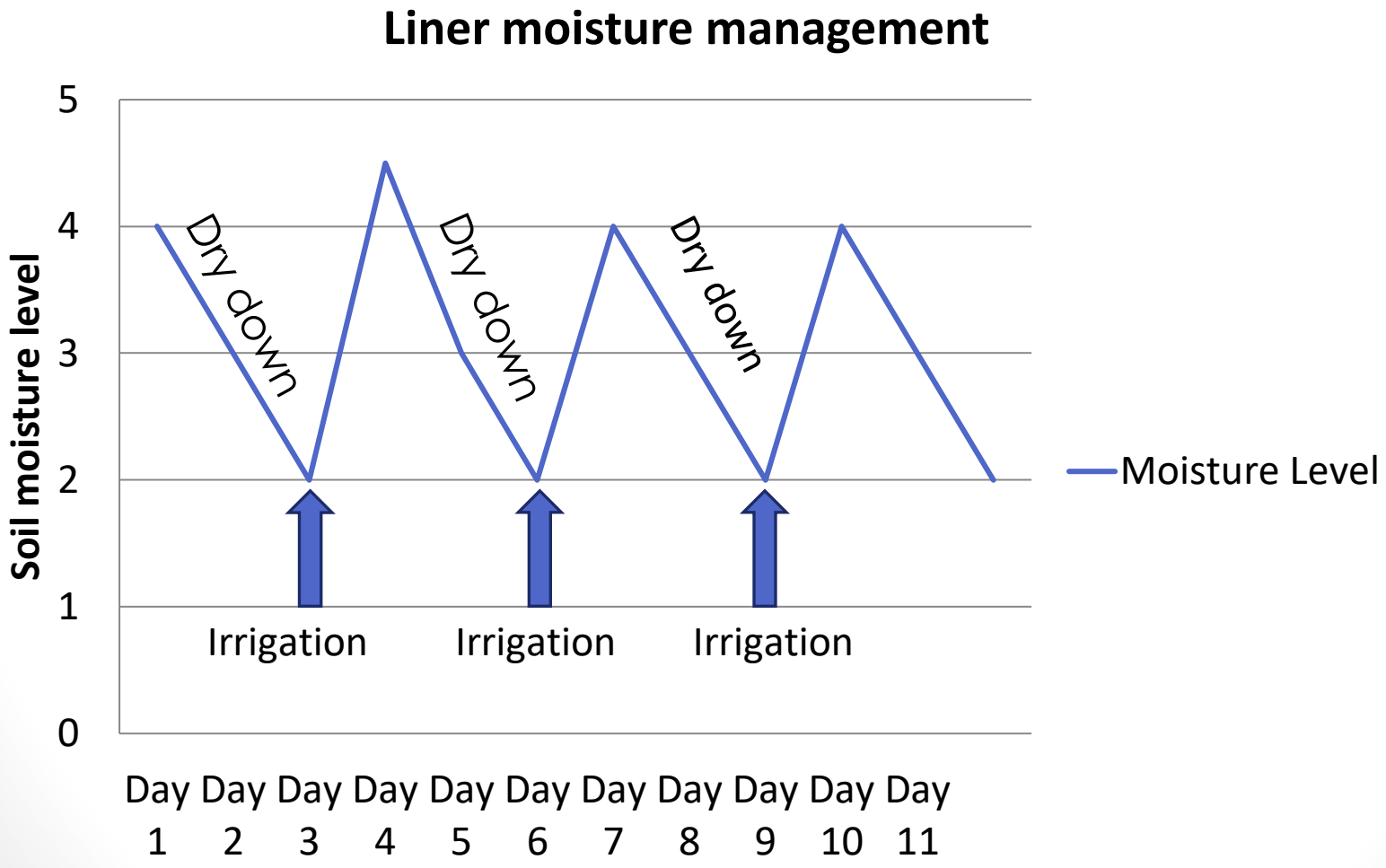
Temperature
Humidity

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

Stage 3: Building root mass

STAGE 3: BUILDING ROOT MASS



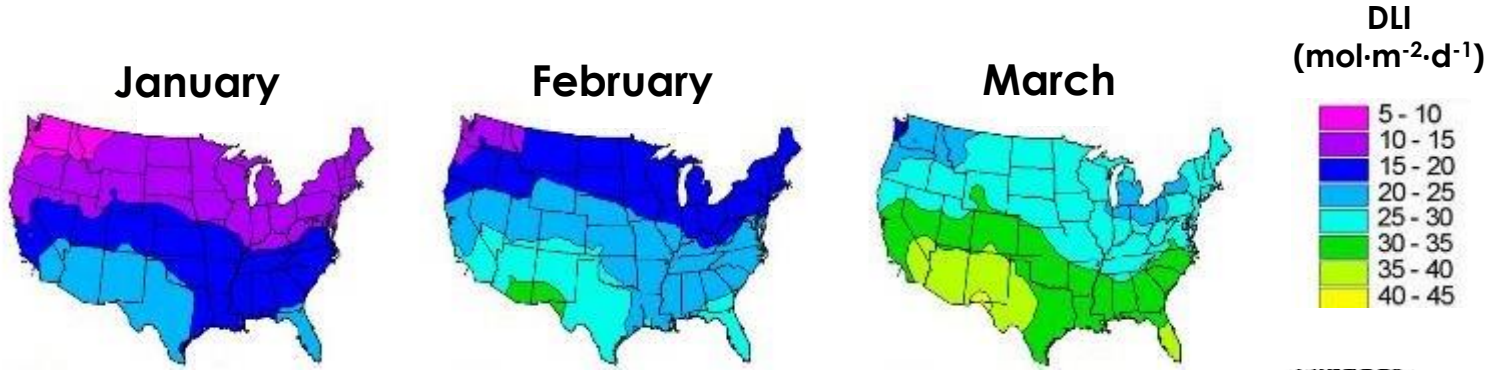
BULKING UP THE TOP

- Bulking is about the green part of the liner
- Be sure to know what you want your liner to look like when it's time to transplant
- You only have 2-3 weeks to bulk up your liner so make it count

Start with the end in mind

STAGE 3: DLI

Avg. Outdoor DLI (mol·m^{-2}·d^{-1})



(Korczynski et al., 2002)

Benefits of Supplemental Light

(Runkle, 2011)

Stage 3: DLI

- During propagation, the DLI outdoors typically ranges from 5 to 20 $mol \cdot m^{-2} \cdot d^{-1}$ across the northern U.S.
- In greenhouses, light levels can be 50% or less of that outdoors because of structures, glazing, shading, and obstructions.
- Therefore, the DLI during propagation can be as low as 2.5 to 5 $mol \cdot m^{-2} \cdot d^{-1}$, and sometimes even lower during extended periods of cloudy weather.


Supplemental Lighting during Liner Production (Cuttings)
Research

New Guinea impatiens 'Harmony White'

Photo taken after 16 d of propagation

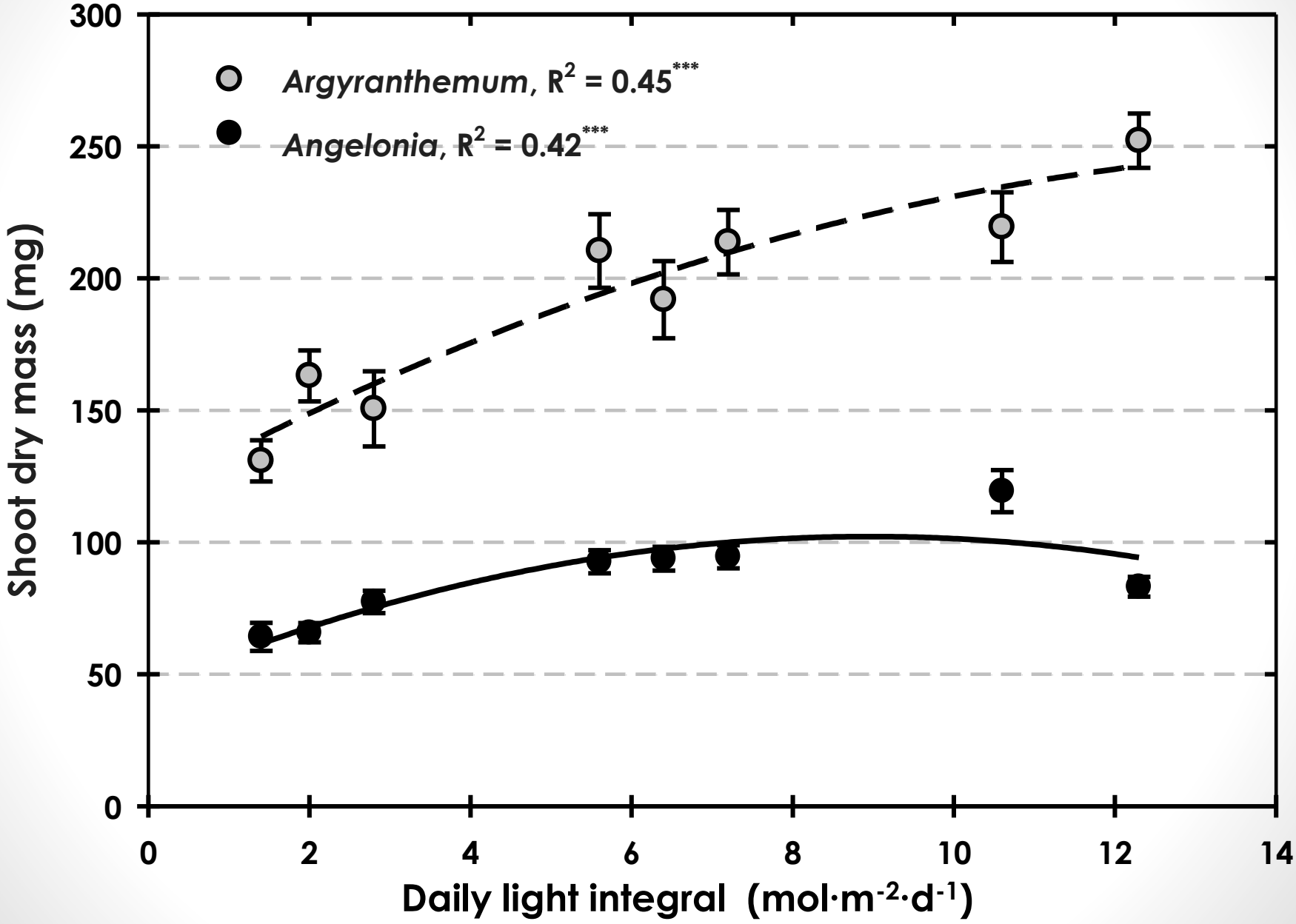
DLI ($mol \cdot m^{-2} \cdot d^{-1}$)

1.3	2.1	4.0	5.7	6.3	10.8
Sunlight			Sun light + HPS		

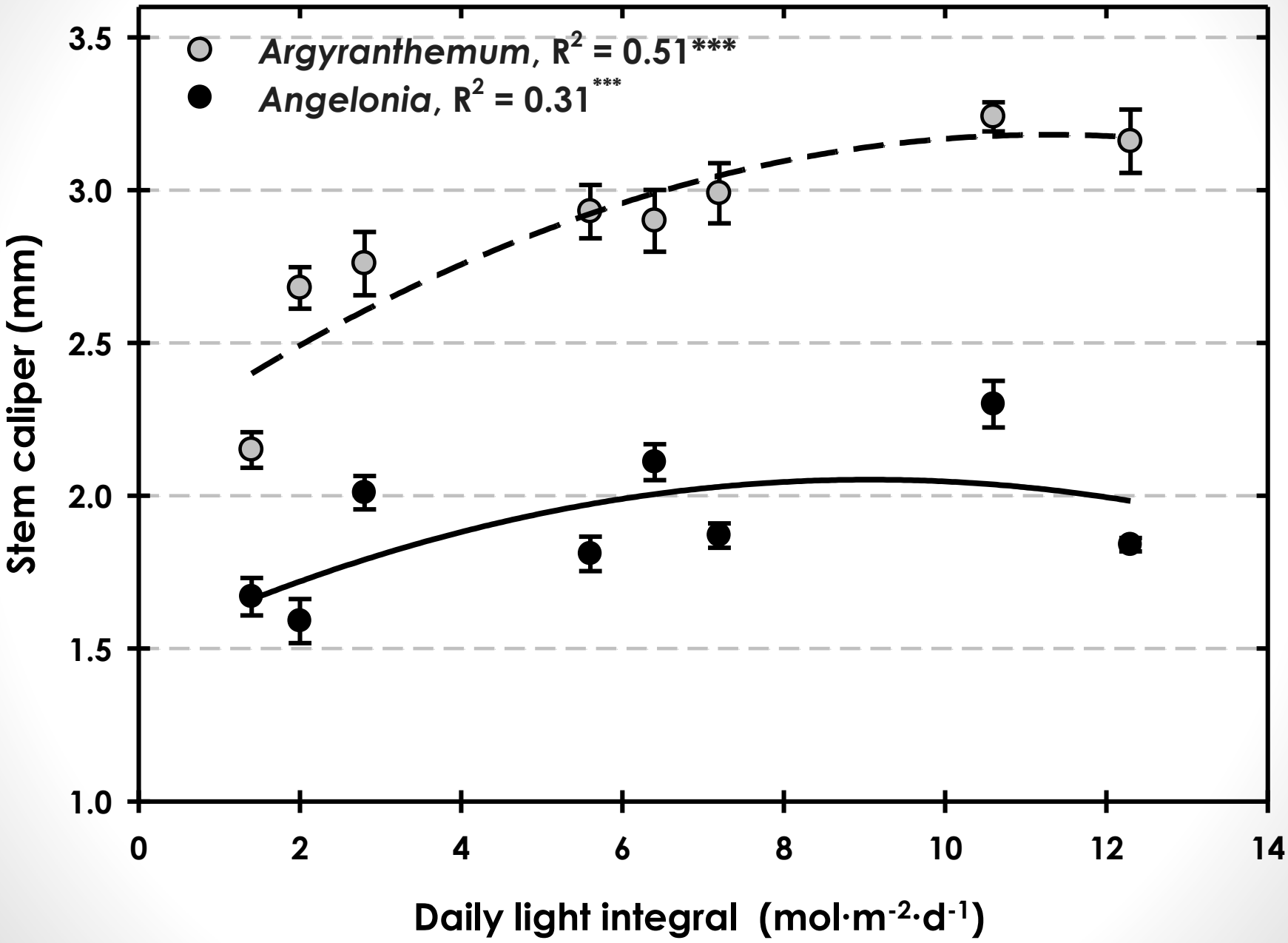
Root dry mass (mg)

8.0	14.5	30.0	35.5	48.5	55.5

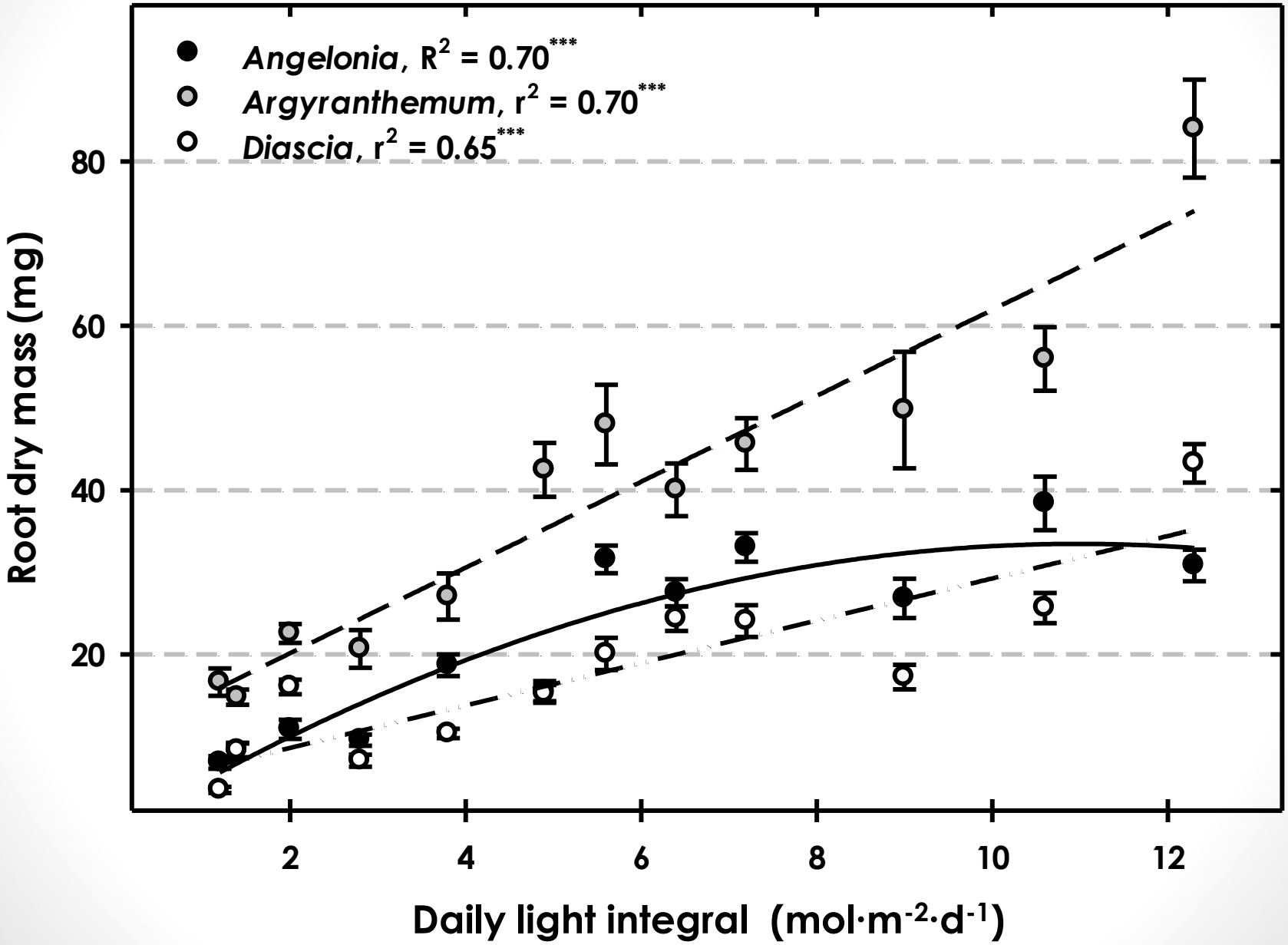
Shoot dry mass increases with DLI



Stem caliper increases with DLI



Root biomass increases with DLI



Angelonia ‘Angel Mist White Cloud’

Photo taken 14 d after transplant

DLI (mol·m^{-2}·d^{-1}) during propagation

1.4	2.0	3.8	5.6	6.4	7.2	10.6	12.3

Shoot dry mass (g) at flower

1.2	1.1	1.1	0.94	0.86	0.77	0.64	0.38

Stage 3: Environmental Parameters

- **Stage 3: after root initiation:**
- Light intensity: After roots have initiated, more moderate light intensities >1000 and <2000 footcandles (>200 and <400 µmol) are generally preferred.
- DLI 5 to 8 $mol \cdot m^{-2} \cdot d^{-1}$

Stage 3: Root development:

- DLI 8 to 12 $mol \cdot m^{-2} \cdot d^{-1}$

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Stage 3: Environmental Parameters

- With bottom heat, maintain substrate 65 to 68 °F and air temperature at 65 to 68 °F.
- Without bottom heat, maintain air temperature at 70 to 72 °F.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Stage 3: Fertility

Have a good plan to recharge

- Use a balanced fertilizer with a full micronutrient package
- 75-150 ppm N should be sufficient

Micronutrients

- Remember that most complete fertilizers will deliver 1 ppm Fe at 200 ppm N so if you are using lower nitrogen levels, you should increase your micronutrients to achieve 1 ppm Fe

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

Pinching in Stage 3

Pinch at the right time so you can plant this liner

Instead of this liner

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant

Stage 3: PGR and Controlled Growth

- Use climate and culture to control growth first
- Know the genetic potential of the varieties in your programs
- Build a PGR plan going into the propagation season
- Utilize less reactive chemicals first
- Lower concentrations and more frequent applications of growth regulators is best to minimize the risk of overregulation

Overregulated liners become shrink

Have a plan!!

Biggest Mistakes of Stage 3

- ✓Not changing the environment
- ✓Poor moisture and light management = poor root development
- ✓Not pinching on time
- ✓Poor fertility plan
- ✓Misusing PGRs

Floriculture
MICHIGAN STATE
UNIVERSITY

Ball FloraPlant.

Stage 4….Toning your Liner

- Factors influencing root development
  - Temperature
    - Substrate temperature drops to help slow top growth.
    - On average, 64 to 66 °F is appropriate. This will allow root development to continue but not create unwanted stem growth or stretch.
    - Air temperature will drop slightly more to further reduce stretch and begin to tone cutting. A general range would be 58 to 62 °F.

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant.

Stage 4….Toning your Liner

Key Points of Stage 4

- Toned liners will perform better after transplant
- Utilize cool and high light space for Stage 4 toning
- Don’t skip this step!

ACKNOWLEDGMENTS

Private horticulture companies and granting agencies that financially support the MSU Floriculture research programs including:

- Ball Horticultural Co.
- Dümmen Orange
- Fine Americas
- Signify
- PL Lighting
- Rakers Robertas
- Jim Faust and Erik Runkle
- Harvey Lang

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Floriculture & Nursery Research Initiative

American Floral Endowment

Floriculture MICHIGAN STATE UNIVERSITY

Ball FloraPlant

THE Fred C. Gloeckner FOUNDATION, INC.