e-GRO Alert

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Rooting for Success: Best Practices in Unrooted Cutting Propagation

Mastering the critical steps of handling and sticking unrooted cuttings is essential for maximizing propagation success, crop uniformity, and overall production efficiency in greenhouse operations.

Successful propagation of unrooted cuttings (URCs) is a cornerstone of efficient greenhouse production. This e-GRO Alert focuses on five critical aspects of handling and sticking URCs: sanitation, timely processing, thorough preparation, precise sticking techniques, and environmental control. By mastering these key areas, growers can significantly improve rooting success, enhance crop uniformity, and boost overall production efficiency. Whether you're a seasoned propagator or new to working with URCs, the following best practices will help you optimize your propagation process and set the foundation for healthy, vigorous floriculture crops.

Figure 1. Example of a clean and well-maintained propagation greenhouse. Photo by: W. Garrett Owen, OSU.

1. Sanitation: The Foundation of Healthy Propagation

Maintaining a clean environment is crucial for successful propagation of URCs (Fig. 1). Pathogens can quickly spread in the warm, humid conditions ideal for callusing and rooting, making sanitation a top priority. Begin by thoroughly cleaning and disinfecting all surfaces that will come into contact with cuttings, including propagation benches or

concrete floors (Fig. 2), trays, and tools. Use a greenhouse-approved disinfectant, following the manufacturer's instructions for concentration and contact time.

Pay special attention to mist nozzles and irrigation systems, as these can harbor pathogens that may spread to newly stuck cuttings. Regularly clean and sanitize coolers used for temporary storage of cuttings to prevent the buildup of mold or bacteria. Implement a strict hand-washing protocol for workers, requiring them to wash hands thoroughly with soap and water or use an alcohol-based hand sanitizer before handling cuttings. Consider using disposable gloves (Fig. 3), changing them between different batches or varieties of cuttings to prevent cross-contamination.

Establish a clean-to-dirty workflow in your propagation area, starting with sanitized areas and moving towards less clean zones. This practice helps minimize the spread of potential contaminants. By prioritizing sanitation, you create an environment that supports healthy root development and reduces the risk of disease outbreaks during the critical propagation phase.

2. Handling Upon Arrival: Timing is Everything

The moment URCs arrive at your facility marks the beginning of a race against time. Unrooted cuttings are living plant material, excised apical meristems, that can quickly deteriorate if not handled properly. Ideally, you should be prepared to stick URCs immediately upon arrival. This means having propagation media prepared, trays ready, and staff on hand to begin the sticking process without delay.

Upon arrival, immediately open boxes and inspect the shipment for quality and potential issues. Check for appropriate

Figure 2. A greenhouse being thoroughly cleaned with a greenhouse-approved disinfectant prior to the introduction of plant material. Photo by: W. Garrett Owen, OSU.

Figure 3. A greenhouse employee wearing disposable gloves while handling and sticking unrooted cuttings. Photo by: W. Garrett Owen, OSU.

Figure 4. Example of greenhouse employees checking and organizing unrooted cuttings in a walk-in cooler because they cannot be immediate stuck and placed in a propagation environment. Photo by: W. Garrett Owen, OSU.

Figure 5. Example of checking the initial moisture level of a propagation substrate. A good rule of thumb is to squeeze a handful of the substrate, and it should hold together without dripping water. Photo by: W. Garrett Owen, OSU.

Figure 6. Example of a pre-dibbled propagation plug that allows unrooted cuttings to be easily inserted into the propagation substrate. Photo by: W. Garrett Owen, OSU.

URC length, caliper, leaf number and size. Look for signs of wilting, damage, stress, disease, or death. Ensure proper labeling and quantity. Use a handheld thermometer or infrared thermometer to determine the cutting-tissue temperature. If you notice any problems, such as off-color, watery, mushy, or chlorotic (yellow) cuttings, or those with many abscised leaves, contact your supplier or sales rep with a detailed description and order information for further assistance.

If immediate sticking is not possible, proper temporary storage is crucial. For short-term storage (less than 24 hours), place cuttings in a cooler maintained at 40 to 50°F (4 to 10°C) with high humidity (Figs. 4A–B). This slows metabolic processes and reduces water loss, helping to preserve cutting quality. Ensure that cooler temperatures are stable and avoid fluctuations that could stress the plant material.

For very short-term holding (a few hours), you may place URCs on a propagation bench under intermittent mist. This keeps them hydrated but should not be considered a long-term solution. When using this method, monitor cuttings closely to prevent over-misting, which can lead to disease issues.

Regardless of the storage method, minimize the time between arrival and sticking. Extended storage can lead to ethylene buildup, leaf chlorosis, and reduced rooting potential. Prioritize sticking the healthiest material first, based on your initial inspection. Refer to the “Unrooted Cutting Sticking Priority” table on page 4 for a detailed list.

3. Preparation: Setting the Stage for Callusing and Rooting Success

Proper preparation of your propagation area and materials is essential for optimal callusing and rooting. Start by selecting a high-quality, pathogen-free propagation substrate that provides adequate aeration and water retention. The ideal substrate should have a balance of large and small pores for aeration and to support both root growth and water management.

Unrooted Cutting Sticking Priority

Immediate **Low**

1	2	3	4
Abutilon	Achillea	Acalypha	Aeonium
Aegopodium	Ageratum	Anagallis	Ajuga
Agastache	Angelonia	Anisodontea	Campanula
Alonsoa	Antirrhinum	Argyranthemum	Chlorophytum
Aloysia	Arctotis	Aster	Chrysanthemum
Alternanthera	Arenaria	Basil	Crassula
Asperula	Artemesia	Bidens	Dorotheanthus
Begonia, Rex	Bacopa	Bracteantha	Echeveria
Caryopteris	Begonia	Centaurea	Houttuynia
Cosmos	Bougainvillea	Ceratostigma	Kalanachoe
Crossandra	Brachyscome	Chrysocephalum	Leucanthemum
Dahlia	Bracteantha	Cineraria	Pachysandra
Daphne	Buddleia	Clerodendron	Pothos
Diascia	Calibrachoa	Coreopsis	Senecio
Duranta	Celosia	Cuphea	Tradescantia
Euphorbia	Cleome	Delospermum	Vinca major
Fuchsia	Coleus	Eupatorium	
Geranium	Dipladenia	Gaillardia	
Geranium, Ivy	Erodium	Galium	
Geranium, Zonal	Eryngium	Gaura	
Heliotrope	Erysimum	Geum	
Heliotropium	Euryops	Glechoma	
Hypericum	Evolvulus	Heliopsis	
Impatiens	Graphtophyllum	Heuchera	
Ipomoea	Hamelia	Hibiscus	
Lantana	Helichrysum	Iberis	
Lavandula	Impatiens	Iresine	
Lithodora	Monarda	Jacobinia	
Lobelia	Nemesia	Jamesbrittenia	
Lobularia	Osteospermum	Lamiastrum	
Mandevilla	Perilla	Lamium	
Ocimum	Petunia	Lophospermum	
Organum	Phlox	Lysimachia	
Perovskia	Portulaca	Lysimachia	
Phygelius	Sanvitalia	Mercardonia	
Plectranthus	Stachy	Nepeta	
Plumbago	Strobilanthes	Onethera	
Poinsettia	Torenia	Penstemon	
Rosemary	Verbena	Ruellia	
Salvia	Viola	Scaevola	
Thunbergia		Scaevola	
Waldstenia		Sedum	
		Solidago	
		Streptocarpella	
		Thymus	
		Veronica	
		Vinca minor	

If using bagged or baled substrate, ensure that the substrate is evenly moist before filling propagation trays. A good rule of thumb is to squeeze a handful of the substrate – it should hold together without dripping water (Fig. 5). If the substrate is too dry, moisten it evenly before filling trays to ensure consistent moisture throughout the root zone. When filling trays, do not pack the substrate as it will reduce the pore spaces and reduce aeration required for root growth.

When preparing to stick URCs, use pre-dibbled propagation plugs or have staff dibble holes in the center of substrate filled propagation trays (Fig. 6). I often see propagation trays stacked on top of each other and press down to dibble the cells (Fig. 7). Again, this will reduce aeration and is not a best management practice. Instead, dibble holes using a metal tool that can be sanitized.

The diameter of the metal tool should create a dibbled hole slightly wider than the URCs stem diameter and deep enough to securely anchor cuttings (Fig. 8). Generally, make the holes about 0.5 to 0.75 inches (1.3 to 2 cm) deep. Cuttings that are stuck to shallow are prone to falling over (Fig. 9A), and cuttings stuck too deep may experience rooting challenges due to the lack of oxygen or could potentially rot (Fig. 9B).

Consider the use of rooting hormones, especially for species known to be difficult-to-root or when uniformity is crucial. Auxin-based compounds, particularly indole-3-butyric acid (IBA), can stimulate faster and more uniform root development. Traditional application methods include powder and liquid dip formulations (Fig 10A–B). When using powder hormones, tap off excess to avoid overapplication, which can inhibit rooting. For liquid dips, follow the manufacturer's recommendations carefully.

Figure 7. Example of propagation trays stacked on top of each other and pressed together to dibble each cell. This reduces substrate aeration and is not a best management practice. Photo by: W. Garrett Owen, OSU.

Figure 8. Example of an unrooted coral bells (*Heuchera*) cutting that was inserted into a dibbled propagation cube at a depth that anchored the cutting thereby preventing it from falling over or out of the cell. Photo by: W. Garrett Owen, OSU.

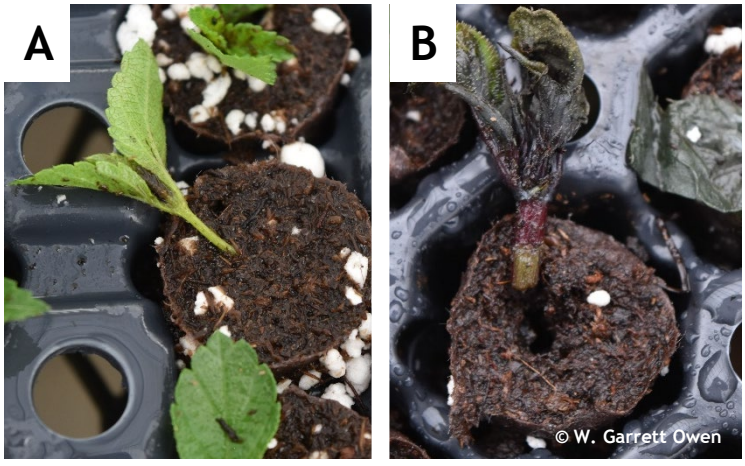

Figure 9. An example were a (A) lantana (*Lantana*) cutting was stuck to shallow and fell out of the cell compared to a (B) New Guinea impatiens (*Impatiens hawkeri*) cutting stuck too deep and rotted. Photo by: W. Garrett Owen, OSU.

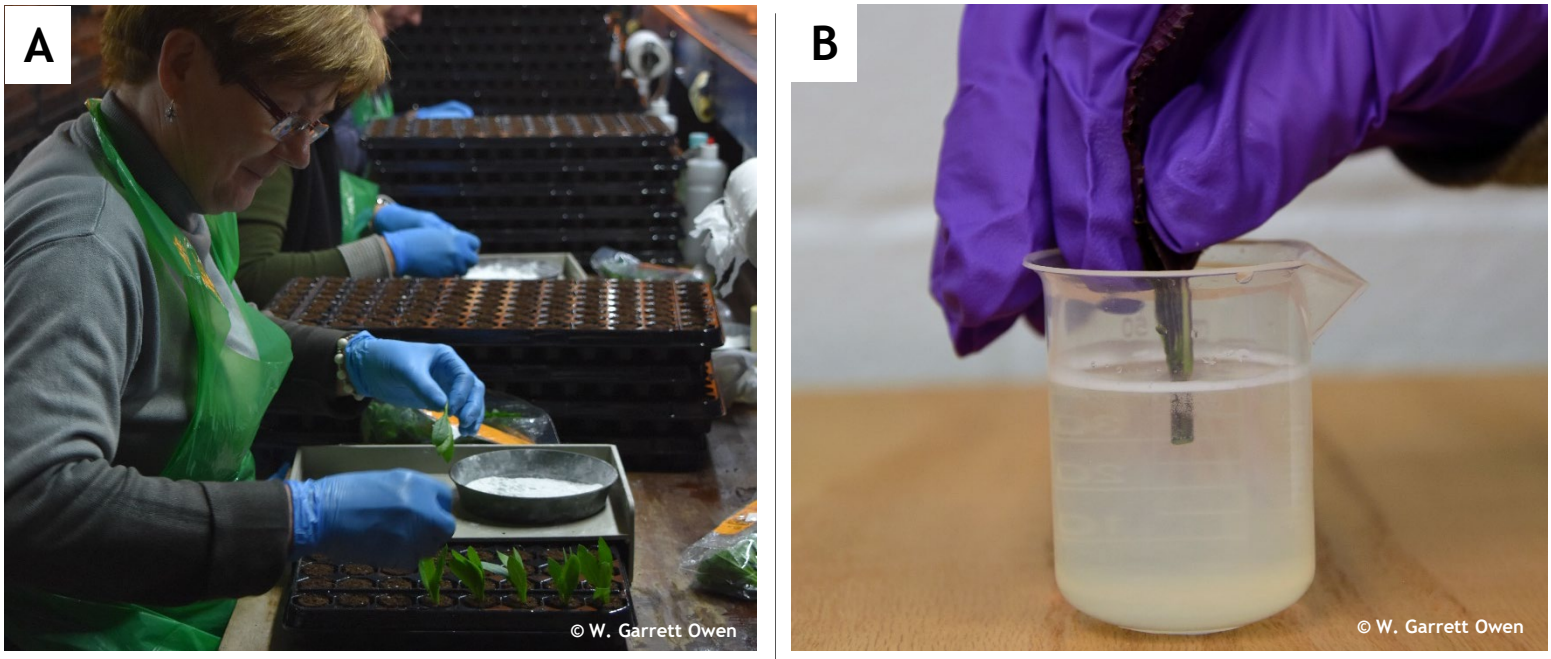

Figure10. Traditional application methods of auxin-based compounds, particularly indole-3-butyric acid (IBA), include (A) powder and (B) liquid dip formulations. Photos by: W. Garrett Owen, OSU.

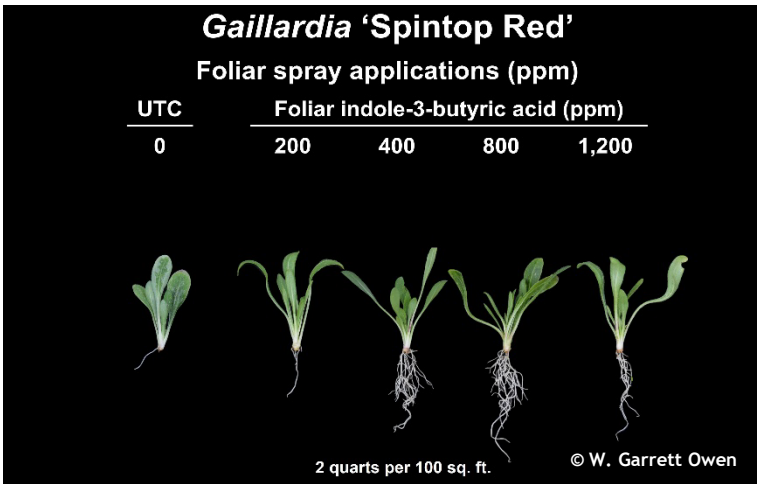

Figure 11. Example of foliar indole-3-butyric acid (IBA) spray applications to promote rooting. Photo by: W. Garrett Owen, OSU.

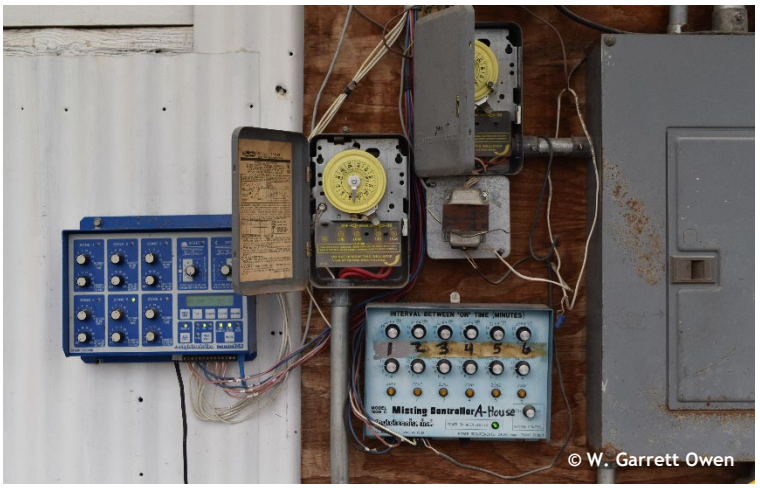

Figure 12. Example of greenhouse misting systems and time clocks being checked. Photo by: W. Garrett Owen, OSU.

An innovative alternative to these traditional methods is the foliar IBA spray application. Products such as Advocate®, manufactured by Fine Americas, Inc., offer a labor-saving option that can be applied after sticking cuttings. Apply foliar sprays within 24 hours of sticking URCs, using concentrations ranging from 80 to 400 ppm for annuals and perennial cuttings (Fig 11), and up to 1,500 ppm for more difficult-to-root herbaceous perennial species. In general, apply the foliar spray at a volume of 2 to 4 quarts per 100 sq. ft. of bench space, ensuring thorough coverage. For optimal absorption, maintain a mist-free period of one to two hours after application. Refer to the Advocate® Guide for further details and always conduct small in-house trials to determine the most effective concentration and application method for your specific crops and conditions.

Prepare your propagation area by adjusting environmental controls in advance. Check misting system clocks (Fig. 12) and nozzles, ensure proper lighting (natural or supplemental), and adjust air and root-zone temperature setpoints and controls to create the ideal rooting environment before cuttings arrive.

4. The Sticking Process: Precision & Care

Training and Technique

The process of sticking URCs demands a careful balance between speed and precision. Thorough staff training is essential to ensure consistency across all propagation trays. Demonstrate the correct sticking depth, emphasizing that cuttings should be inserted into dibbled holes deep enough to stand upright and support themselves, typically 0.5 to 0.75 inches (1.3 to 2 cm) deep, depending on the cutting size. Stress the importance of avoiding burying leaves or nodes, as this can lead to rotting. Conduct regular quality checks and provide ongoing feedback to maintain high standards.

Gentle Handling

Proper handling of URCs is crucial to prevent damage and stress. Train workers to hold cuttings by the stems, avoiding contact with leaves whenever possible. This reduces the risk of bruising or tearing leaf tissue or spreading pathogens. Insert URC bases into the dibbled substrate and demonstrate the correct pressure to apply when firming the media around the cutting to ensure good contact without compacting the substrate excessively.

Workflow Optimization

Efficiency in the sticking process is key to maintaining cutting quality and worker productivity. Organize your workflow to minimize unnecessary movement and maximize output. Set up sticking stations ergonomically, with all necessary materials (cuttings, trays, dibble tools, etc.) within easy reach. Consider using carts or conveyor systems to move trays efficiently. Implement sticking boards or templates to ensure consistent centering and spacing between cuttings. This uniform spacing is crucial for even growth, air circulation, and ease of future handling. It also helps in optimizing bench space utilization.

Post-Sticking Care

Immediate post-sticking care is critical for cutting survival. As soon as a tray is filled, place it in a high humidity environment such as a plastic covered cart or under mist to prevent wilting. The first misting after sticking is particularly important as it settles the substrate around the cutting and provides immediate hydration. This initial misting should be thorough but not excessive to avoid waterlogging. Be prepared to adjust misting frequency based on environmental conditions (temperature, humidity, and light intensity) and the specific needs of different plant species. Some cuttings may require more frequent misting initially, while others may need less. Monitor the cuttings closely in the first 24 to 48 hours and adjust misting as needed to maintain turgidity without promoting disease. Remember, mist should be deployed to keep cuttings turgid and not a form of irrigation.

5. Environmental Control: Nurturing Root Development

Temperature Management

Creating and maintaining the ideal environment for root initiation and development is a critical aspect of successful propagation. Temperature management is paramount – aim for a consistent root-zone temperature ranging between 70 to 74°F (21 to 23°C) during callusing and 66 to 70°F (19 to 21°C) during rooting. Use heated propagation benches to maintain stable root zone temperatures, which can significantly hasten the rooting process (Fig. 13). Monitor media temperature regularly using thermometers or sensors to ensure consistency. Remember that air temperature and root-zone temperature can differ, so manage both independently if possible.

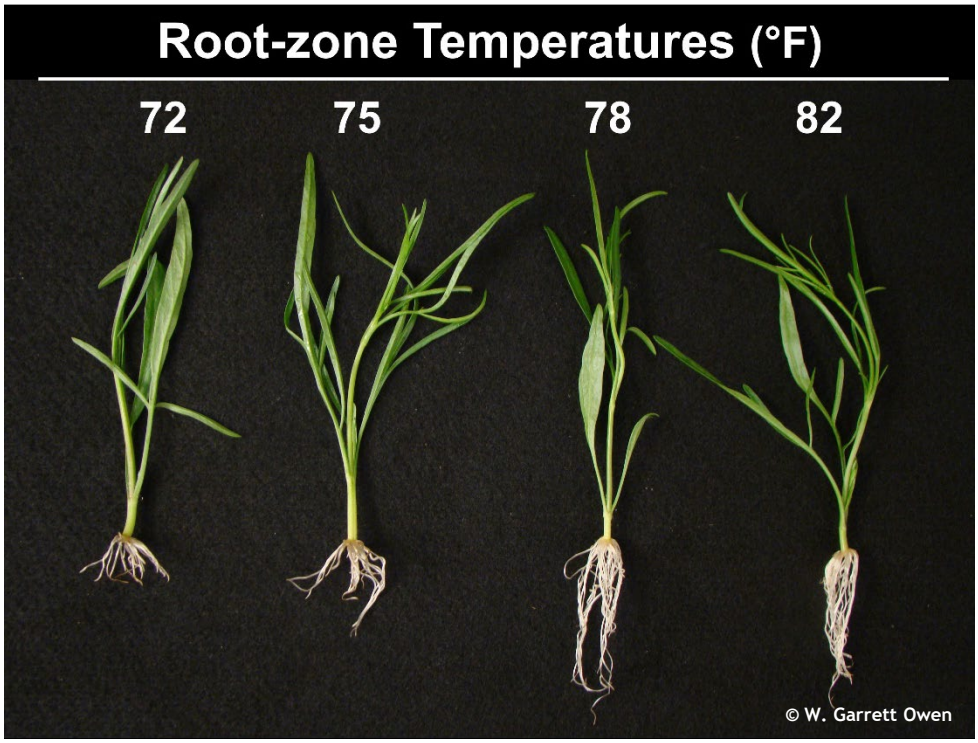

Figure 13. Unrooted cuttings of tickseed (*Coreopsis*) propagated with root-zone temperature set points of 72, 75, 78, or 82 °F (22, 24, 26, and 28 °C). Cuttings were propagated under a daily light integrals of 10.2 $mol \cdot m^{-2} \cdot d^{-1}$. No rooting hormone application occurred. Photo taken 8 days after sticking unrooted cuttings in a propagation environment. Photos by: W. Garrett Owen, OSU.

Air temperature plays a crucial role in the propagation of unrooted cuttings, influencing both root and shoot development. While root-zone temperature is often the primary focus, managing air temperature is equally important for successful propagation. Generally, air temperature during callusing should be maintained between 75 to 80˚F (24 to 27˚C) during days and 70 to 74˚F (21 to 23˚C) during nights. During rooting, maintain air temperatures between 75 to 80˚F (24 to 27˚C) during days and lower to 60 to 68˚F (16 to 20˚C) during nights. If root-zone heat is not available, air temperature should be increased to 77 to 80˚F (25 to 27˚C) to ensure adequate medium temperature. Some adjustments maybe needed depending on your propagation environment.

It's important to note that maintaining air temperature slightly lower than medium temperature can be beneficial, as it controls shoot growth and promotes root development. This temperature differential, typically around 5 to 10˚F cooler for air compared to the root zone, allows roots to grow more quickly than shoots. However, growers should be cautious, as excessively high air temperatures can increase transpiration rates and potentially stress unrooted cuttings. Conversely, if air temperatures are too low, rooting will be delayed due to insufficient metabolic activity.

During peak propagation season (December through March), careful management of air temperature becomes even more critical. Growers should monitor both air and root zone temperatures regularly, adjusting heating systems as needed to maintain optimal conditions for rooting. By balancing air temperature with other environmental factors such as humidity, light, and root-zone heating, propagators can create an ideal environment for rapid, uniform rooting and high-quality liner production.

Humidity and Vapor Pressure Deficit (VPD) Control

Humidity management is critical for URCs to reduce transpiration and prevent water stress. During the initial stages of propagation, maintain relative humidity between 85% and 95%. However, be cautious of constantly saturated conditions, which can promote disease. Use a variable frequency or intermittent misting system that can be adjusted

Figure 14. Example of a greenhouse deploying fine-particle mist to manage vapor pressure deficit (VPD). Photo by: W. Garrett Owen, OSU.

Figure 15. Example of petunia (*Petunia*) cuttings propagated under long-day conditions thereby inducing premature flower bud development and flowering. Photo by: W. Garrett Owen, OSU.

based on environmental conditions and the stage of root development.

Incorporate vapor pressure deficit (VPD) management into your humidity control strategy (Fig. 14). Vapor pressure deficit, which measures the difference between the amount of moisture in the air and how much moisture the air can hold when saturated, is a more precise way to manage plant water relations. For most propagation environments, aim for a VPD between 0.3 to 0.8 kPa. This range promotes optimal water uptake without causing excessive transpiration stress on the cuttings.

If your greenhouse environmental control system does not offer VPD management, then try use the new e-GRO VPD calculator. Start by entering the propagation air temperature and relative humidity values. If VPD is too low or high, then adjust the air temperature and misting frequency and duration. Monitor the environment and re-enter the air temperature and relative humidity readings into the calculator until a desirable VPD is achieved. Continuous monitoring of the propagation air temperature and relative humidity is needed to adjust VPD.

Lighting Control

Photoperiod (duration) and light intensity are two critical factors during URC propagation. Ideally, URCs should be vegetative and lack flower buds and flowers. Propagators can manipulate and manage the photoperiod to prevent long-days plants, such as petunia, from premature flowering during propagation and toning (Fig. 15). The general recommended photoperiod to maintain during propagation of most annual bedding plants is 12 to 13 hours.

Propagators should also monitor light intensity carefully. During callusing, maintain light levels between 120 to 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ until root initials develop. As roots begin to form, light intensity can be increased to 200 to 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$. When roots have filled about half the liner, light intensity can be further increased to 500 to 800 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

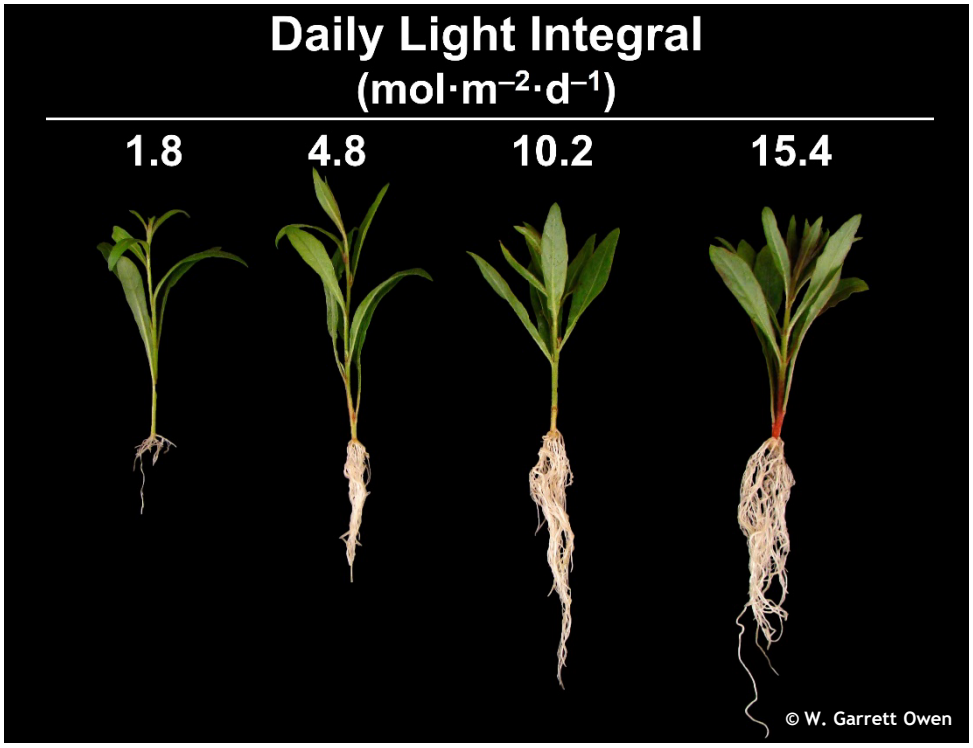

Figure 16. Unrooted cuttings of gaura (*Oenothera*) propagated under daily light integrals of 1.8, 4.8, 10.2, or 15.4 mol·m^{-2}·d^{-1} and with a root-zone temperature set point of 75 °F (28 °C). No rooting hormone application occurred. Photo taken 8 days after sticking unrooted cuttings in a propagation environment. Photos by: W. Garrett Owen, OSU.

Excessive light can increase transpiration rates and lead to water stress in unrooted cuttings and death. As such, consider using shade curtains to reduce cutting stress.

During low-light seasons and under short-days or in propagation facilities with limited natural light, supplement and extend the day with high-pressure sodium (HPS) lamps or light-emitting diodes (LED). When photoperiod and light intensity are integrated together, then propagators can calculate the daily light integral (DLI). During callusing, a lower DLI of 4 to 5 mol·m^{-2}·d^{-1} is recommended and should be increased to 8 to 12 mol·m^{-2}·d^{-1} during rooting (Fig. 16) Propagators can try the new e-GRO LightCalc to determine DLI by entering the photoperiod and light intensity values.

Carbon Dioxide and Air Circulation

Carbon dioxide (CO_2) is essential for photosynthesis and can significantly enhance rooting success when managed properly. In sealed propagation environments, enrich CO_2 levels to 800 to 1,000 ppm to accelerate photosynthesis and improve rooting efficiency. However, not all greenhouses have CO_2 enrichment capabilities so ventilation can be deployed and to prevent stagnant air conditions, which can lead to disease development or uneven environmental conditions.

Ensure proper air circulation throughout the propagation area using horizontal airflow fans (HAF). Good air movement prevents the buildup of excess humidity around cuttings, reduces the risk of fungal diseases, and promotes uniform temperature and humidity distribution. Avoid directing airflow directly onto cuttings, as this can increase transpiration rates and cause water stress. Instead, position fans to create gentle air movement across the canopy. Regularly inspect fans and ventilation systems to ensure they are functioning correctly and providing consistent airflow.

Monitoring and Adjustment

Regular monitoring and proactive adjustments are essential for maintaining optimal environmental conditions during propagation. Inspect cuttings daily for signs of stress,

such as wilting, chlorotic leaves, or uneven growth, as well as for signs of disease or pest infestations. Early detection allows for timely interventions that can prevent small issues from escalating into significant problems.

Use environmental control systems with data logging capabilities to track key parameters such as temperature, humidity, VPD, light levels, and CO2 concentrations over time. Analyze this data regularly to identify trends or fluctuations that may require adjustments to your protocols. For example, if light levels are consistently below target DLI thresholds in winter months, increase supplemental lighting duration or intensity.

Be prepared to fine-tune environmental controls based on observations of plant responses and progress in root development. Different species – and even different varieties – may have unique requirements for temperature, humidity, light intensity, or VPD. Flexibility is key; adjust your practices as needed to optimize conditions for each crop. By maintaining close attention to environmental factors and making informed adjustments, you can ensure successful rooting and uniform growth across all propagation trays.

By mastering these five key areas – sanitation, timely handling, thorough preparation, careful sticking, and precise environmental control – you'll set the stage for consistently successful propagation of URCs. This attention to detail during the critical early stages of plant production will pay dividends in the form of healthier, more uniform crops and improved overall greenhouse efficiency.

DÜMMEN ORANGE®

I gratefully acknowledge Dümmen-Orange for unrooted cuttings to create Figures 11, 13, and 16.

fine
Excellence in PGR Technology

I gratefully acknowledge Fine Americas, Inc. for Advocate® to create Figure 11.

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