Keys to Rooting Success

Read on for tips on propagating difficult or slow-rooting or -growing cuttings with foliar rooting sprays and/or plant growth regulators.

BY ANNIKA KOHLER, NATHAN DURUSSEL AND ROBERTO LOPEZ

Rooting hormones such as IBA (indole butyric acid) and NAA (napthaleneacetic acid) have been staples in the greenhouse and nursery industry for years to readily promote rooting success of slow- or difficult-to-root cuttings. Most commonly, IBA or IBA + NAA have been applied as a powder or solution to the basal end of cuttings before sticking them into liner trays. In recent years, water-soluble IBA (i.e., potassium salt formulated K-IBA or acid form IBA) sprays onto the foliage of cuttings once in the propagation environment have gained popularity among growers. This reduces labor and material costs, the potential to spread diseases, and possible plant desiccation or leaf distortions from IBA dissolved in alcohol.

The focus of our first experiment was to quantify rooting success in terms of root dry mass of a single foliar application of IBA compared to a traditional basal dip of IBA + NAA. In a second experiment, we compared the effect of a foliar applied IBA to a foliar spray containing kinetin (KN) + gibberellic acid (GA_3) + IBA alone or as a follow up application 14 days after an initial IBA spray on shoot and root biomass of young plants.

THE STUDY

Bedding plants that are considered difficult or slow-to-root were selected for this study. Herbaceous stem-tip cuttings of dahlia 'Venti Passion Fruit' (*Dahlia pinnata*), geranium 'Sunrise Lavender + Red Eye' (*Pelargonium × hortorum*), osteospermum 'Serenity Lavender Frost' (*Osteospermum ecklonis*), scaevola 'Scalora Brilliant' (*Scaevola* hybrid) were used for Experiment 1, and brachyscome 'Radiant Magenta' (*Brachyscome hybrida*), lantana 'Dallas Red' (*Lantana camara*), and scaevola 'Blue Fan' were used for Experiment 2. All cuttings were stuck into a porous substrate that consisted of peat moss, perlite and vermiculite and in 72-cell trays (28-mL) with the exception of geranium, which was stuck into 72-cell trays (44-mL).

Trays were placed in a glass-glazed greenhouse at Michigan State University (East Lansing, Michigan) with a vapor pressure deficit of 0.3 kPa and an average air and root-zone temperature of 72 and 75° F, respectively. A 16-hour photoperiod (6 a.m. to 10 p.m.) consisted of natural days and supplemental lighting via high pressure sodium lamps. The daily light integral (DLI) ranged from high (~11 $mol·m^{-2}·d^{-1}$) to very high (~15 $mol·m^{-2}·d^{-1}$) in Experiment 1 and was moderate (8 $mol·m^{-2}·d^{-1}$) in Experiment 2. Overhead mist containing 60-ppm nitrogen was provided as necessary from 5 to 12 a.m. based on the light intensity and was discontinued as the study progressed.

HORMONE TREATMENTS

For Experiment 1, prior to sticking cuttings into the tray, the basal end of a subset of cuttings of each genus were either dipped in a solution containing 100-ppm IBA + 50 ppm NAA or 200-ppm IBA + 100 ppm NAA (Dip'N Grow Liquid Rooting Concentrate;). Another subset of cuttings received a foliar

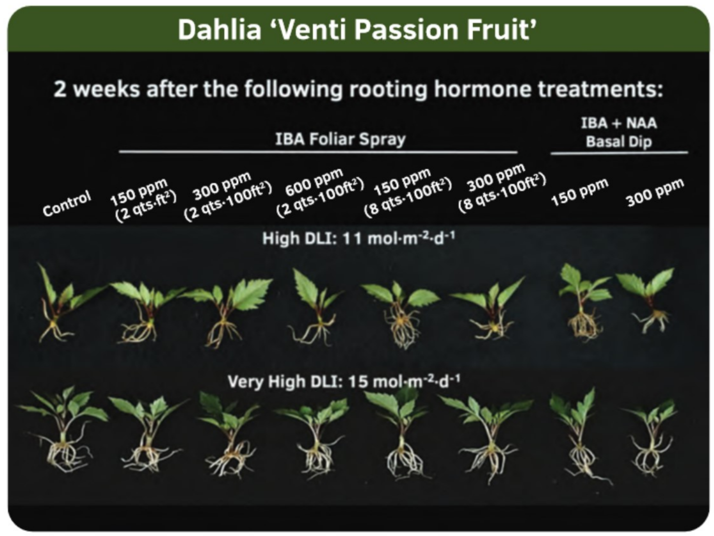

Figure 1. Rooting of dahlia 'Venti Passion Fruit' after two weeks under an average DLI of 11 or 15 $mol·m^{-2}·d^{-1}$ and treated with a foliar spray application of 0-, 150-, 300- or 600-ppm IBA at 2 or 8 quarts per square foot or dipped in a 150- or 300-ppm solution of IBA + NAA.

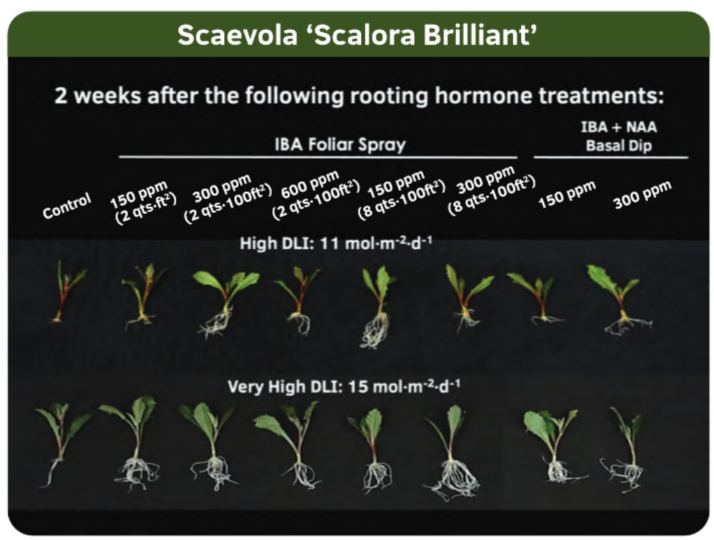

Figure 2. Rooting of Scaevola 'Scalora Brilliant' after two weeks under an average DLI of 11 or 15 $mol·m^{-2}·d^{-1}$ and treated with a foliar spray application of 0-, 150-, 300- or 600-ppm IBA at 2 or 8 quarts per square foot or dipped in a 150- or 300-ppm solution of IBA + NAA.

spray of reverse-osmosis water (0 ppm; control) or 150-, 300- or 600-ppm IBA (20% IBA Advocate) at 2 qts/100 ft^2 or 150 or 300 ppm at 8 qts/100 ft^2 approximately 20 hours after cuttings were manually stuck into trays. Mist was discontinued for approximately three hours to allow cuttings to absorb the rooting hormone.

For Experiment 2, cuttings received a foliar spray application of reverse-osmosis water (0 ppm; control), 6.25 or 15.6 $mL·L^{-1}$ KN + GA_3 + IBA [0.010% KN, 0.005% GA_3, and 0.005% IBA (Crest)] at 2 qts/100 ft^2, 150- or 300-ppm IBA (Advocate) at 2 qts/100 ft^2 or 8 qts/100 ft^2 approximately 20 hours after cuttings were stuck into the trays. For treatments receiving 300-ppm IBA at 2 qts/100 ft^2, a subset of cuttings received a spray application of 6.25 or 15.6 mL·L-1 KN + GA_3 + IBA at 2 qts/100 ft^2 14 d after sticking cuttings.

After 14 (Experiment 1) or 21 days (Experiment 2) of propagation, 10 cuttings per genus per treatment were removed from trays and the substrate was gently rinsed from the roots. For Experiment 1, the root dry mass and time to produce a marketable liner were recorded. For Experiment 2, the stem length, root and shoot dry mass were recorded.

RESULTS

No visible signs of phytotoxicity were observed on any cutting treated with a foliar or basal rooting hormone. For Experiment 1, dahlia and geranium had comparable rooting (root dry mass) and were pullable after three weeks when dipped in 200-ppm + 100-ppm IBA + NAA or sprayed with 150- or 300-ppm IBA at 2 or 8 qts/100 ft^2 under a high DLI of 11 $mol·m^{-2}·d^{-1}$ (Figure 1).

Cuttings were not pullable for four to five weeks if they did not receive a rooting hormone application. Under the same DLI, the root dry mass of osteospermum was 62 to 145% and scaevola was 112 to 136% greater when cuttings received a foliar application of 300-ppm IBA at 8 qts/100 ft^2 compared to a basal dip of 150-ppm IBA + 50 ppm NAA or 200 ppm IBA + 100-ppm NAA, respectively (Figures 2 and 3).

Under a very high DLI of 15 $mol·m^{-2}·d^{-1}$, the root dry mass was reduced regardless of hormone treatment, with only dahlia and geranium having some response to rooting hormone (Figure 1). However, in all cases, providing rooting hormone via a foliar spray or basal dip resulted in a greater root dry mass than no rooting hormone.

For Experiment 2, the stem length varied among genera. For instance, the stem length of brachyscome was 21% shorter when treated with 6.25 or 15.6 $mL·L^{-1}$ KN + GA_3 + IBA than those cuttings treated with 300-ppm IBA at 8 qts/100 ft^2. In contrast, stem length of scaevola was 24% greater when treated with 6.25 $mL·L^{-1}$ KN + GA_3 + IBA than those cuttings treated with a 300-ppm foliar spray of IBA at 2 or 8 qts/100 ft^2, whereas lantana stem length was unaffected (Figure 4).

For brachyscome, lantana, and scaevola, rooting improved when the cuttings received a foliar application of 150- to 300-ppm IBA at 8 qts/100 ft^2, similar to Expt. 1. The shoot dry mass was generally greater for brachyscome, lantana, and scaevola when KN + GA_3 + IBA was used alone or with IBA (Figure 4).

CONCLUSION

Under a moderate to high DLI, dahlia, geranium, osteospermum and scaevola cuttings treated with 300-ppm IBA at 2 to 8 qts/100 ft^2 had comparable or greater root growth than cuttings that were dipped in IBA + NAA. Not surprisingly, for all genera propagated under a very high DLI of 15 $mol·m^{-2}·d^{-1}$, rooting was reduced compared to cuttings rooted under a DLI of 8 to 12 $mol·m^{-2}·d^{-1}$. A foliar application of 150- to 300-ppm IBA at 2 to 8 qts/100 ft^2 produced full, well-rooted liners of brachyscome, osteospermum, lantana and scaevola within three weeks of stick. A follow up application of 6.25 $mL·L^{-1}$ KN + GA_3 + IBA two weeks after a 300-ppm foliar spray of IBA at 2 qts/100 ft^2 may increase shoot growth of slow growing genera without affecting root growth but needs to be further investigated for longer propagation times and application frequency. gpn

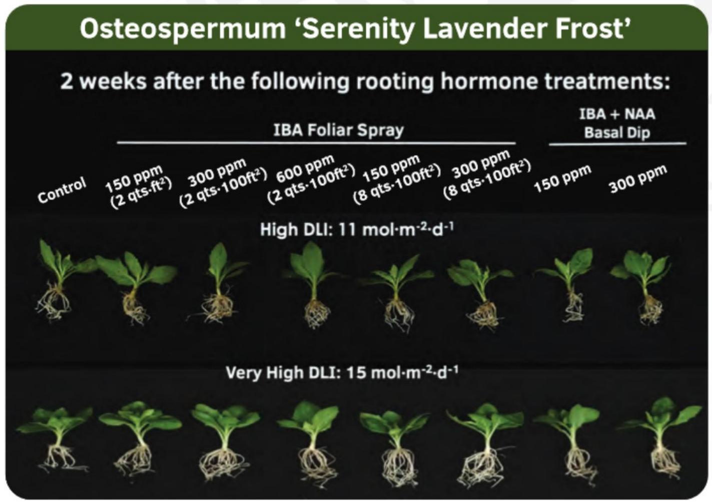

Figure 3. Rooting of Osteospermum 'Serenity Lavender Frost' after two weeks under an average DLI of 11 or 15 $mol·m^{-2}·d^{-1}$ and with a foliar spray application of 0-, 150-, 300- or 600-ppm IBA at 2 or 8 quarts per square foot or dipped in a 150- or 300-ppm solution of IBA + NAA.

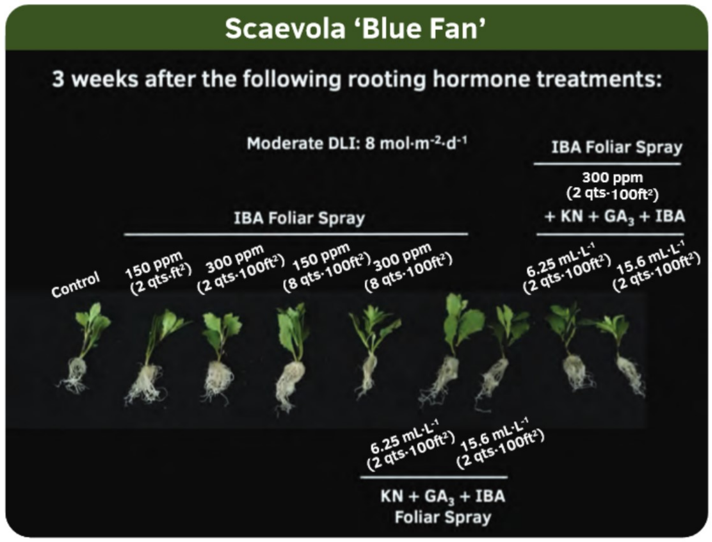

Figure 4. Rooting of Scaevola 'Blue Fan' after three weeks under an average DLI of 8 $mol·m^{-2}·d^{-1}$ and treated with a foliar spray application of 0-, 150- or 300-ppm IBA at 2 or 8 quarts per square foot, or a foliar spray application of 6.25 or 15.6 $mL·L^{-1}$ kinetin + gibberellic acid + IBA (KN + GA_3 + IBA) or 150- or 300-ppm solution of IBA, or a foliar spray of 300-ppm IBA followed by a 6.25 or 15.6 $mL·L^{-1}$ solution of KN + GA_3 + NAA 14 days later.

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Annika Kohler is a research technician, Nathan DuRussel is a greenhouse technician, and Roberto Lopez is an associate professor and controlled environment/floriculture Extension specialist in the Department of Horticulture at Michigan State University. Lopez can be reached at rglopez@msu.edu.

Do Micro Drenches on Annuals and Perennials Work?

Research at Michigan State University indicates that micro drenches can effectively control aggressive annuals and perennials during production without stunting plants for consumers.

By Roberto G. Lopez

ABOUT THE AUTHOR: Roberto Lopez is an Associate Professor and Controlled Environment/Floriculture Extension Specialist in the Department of Horticulture at Michigan State University. rglopez@msu.edu

Plant growth retardants (PGRs) can be applied as sprays to the stems or leaves of plants, or to the growing substrate in the form of drenches, sprenches (hybrid of a spray and a drench), plug or liner dips, and bulb, rhizome, or tuber dips. A PGR drench is an application of a relatively large volume of a PGR solution to a substrate at a concentration approximately half or less of what is used in sprays. Drenches are applied to inhibit extension growth of aggressive crops for a long period of time (e.g., petunia, sweet potato vine, etc.) or to stop extension growth once a plant reaches its final desired height (e.g., bulbs, Easter lilies, and poinsettias).

Table 1: Volume Based on Container Size

The table below highlights the volume of plant growth regulator (PGR) required for various container sizes to provide micro drench rates of 0.125 to 2 ppm and milligrams of PGR active ingredient per container.

Container Diameter (inches)	Drench Volume (fluid ounces/ container)	Micro Drench PGR Rate (ppm) 0.125	0.25	0.5	0.75	1	2
		milligram (mg) of PGR active ingredient/container					
4	2	0.0079	0.0158	0.0315	0.0473	0.063	0.125
5	3	0.0117	0.0235	0.047	0.0705	0.094	0.188
6	4	0.0156	0.0313	0.0625	0.0938	0.125	0.25
8	10	0.0391	0.0782	0.1565	0.2348	0.313	0.625
10	25	0.0979	0.1958	0.3915	0.5873	0.783	1.56
10-inch hanging basket	15	0.0588	0.1175	0.235	0.3525	0.470	0.939
12	40	0.1563	0.3125	0.625	0.9375	1.25	2.5

Substrates Impact on PGR Drench Effectiveness

A drench can provide a long-lasting response because the PGR is retained by the substrate components and is available to the roots over an extended period. Substrate composition can also affect the effectiveness of drenches. It is well established that pine bark, when included in substrate, reduces the effectiveness of PGR drenches. Therefore, if you are drenching plants in substrates that contain pine bark, you may need to increase the active ingredient concentration by as much as 25% to achieve better height control. However, drench activity is unaffected by substrates containing rice hulls or wood fiber.

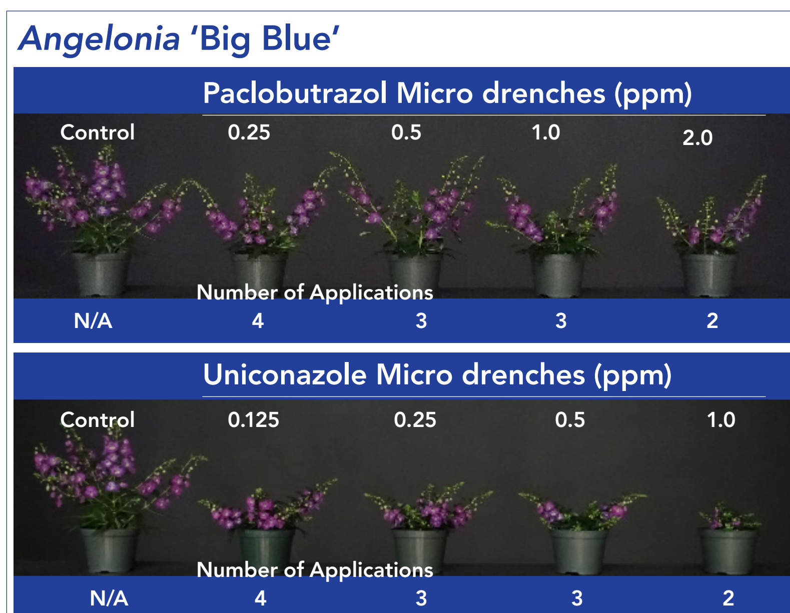

Figure 1: Effect of paclobutrazol and uniconazole micro drenches on angelonia.

Drenches Versus Sprays

With drenches, the PGR is absorbed by the roots and transported to the growing points where it inhibits subsequent stem elongation. Drenches can be more desirable than spray applications because they are often only applied once, whereas sprays are often applied multiple times. In addition, sprays applied late in the production cycle can delay flowering or bract size of poinsettia, whereas drenches typically do not have this effect. However, drenches can be labor intensive depending on the delivery method. They should be applied to moist (but not excessively dry or wet) substrate, and none should leach out of the container. Lastly, if you utilize a subirrigation system to deliver a drench, reduce the rate by 25% to 50%.

Which PGRs Can Be Applied as a Drench?

Not all PGRs are effectively absorbed by roots, as is the case with daminozide (B-Nine and Dazide). PGRs with the active ingredient paclobutrazol (Bonzi, Downsize, Pac O, Piccolo, or Piccolo 10XC) or uniconazole (Concise and Sumagic) are commonly used as drenches. Ancymidol (Abide and A-Rest), chlormequat chloride (Citadel and Cycocel), and flurprimidol (Topflor) are also effective, but either require large amounts to be effective or are cost prohibitive, while ethephon (Florel and Collate) is not registered for use as a substrate drench. As a drench, uniconazole is applied at rates 50% lower than those recommended for paclobutrazol. The appropriate volume of PGR drench solution depends on the container, as outlined in Table 1 on page 16.

The concept of applying several PGR micro drenches earlier and at a lower rate than one drench application is of increasing interest to greenhouse growers that are hesitant of drenches. Micro drenches are generally 1/8th to 1/10th of the traditional rates used for drenches and sprays. Based on research at the University of Florida and by SePRO Corporation utilizing Topflor on poinsettia, micro drenches can lead to toned and uniform plants throughout production. This requires less total PGR than one heavy or stop drench application and does not stunt plants, but it leaves more room for error.

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Micro Drench Guidelines

- Do not utilize on slow-growing species or cultivars
- Apply within five to seven days of transplanting plugs or liners
- Subsequent applications should be made within seven days
- Increase rates by up to 25% if your substrate contains bark
- Apply to moist (but not excessively dry or wet) substrate
- Conduct small trials to determine appropriate rates for your crops and environmental and cultural conditions.

Table 2: Summary of Our Results

The table below highlights the effective rates and number of uniconazole or paclobutrazol micro drench applications required to produce compact and marketable crops and potential delay in time to flower.

Crop	Uniconazole (ppm) and [number of applications]	Flowering delay (days)	Paclobutrazol (ppm) and [number of applications]	Flowering delay (days)
Angelonia	Rates too high	3 to 12	0.25 [4 applications] 0.5 [3 applications] 1.0 [3 applications]	5 to 8
Dianthus	0.125 [3 applications]	No delay	0.50 [3 applications] 1.0 [3 applications] 2.0 [3 applications]	1 to 6
Hibiscus	0.25 [1 application] 0.5 [1 application]	5 to 6	0.50 [2 applications] 1.0 [1 application]	3 to 5
Lantana	0.125 [3 applications] 0.25 [3 applications]	No delay	0.25 [3 applications] 0.5 [3 applications] 1.0 [3 applications]	No delay
New Guinea impatiens	Rates too high			
Upright Petunia	0.125 [3 applications] 0.25 [3 applications] 0.5 [3 applications] 1.0 [3 applications]	No delay to 9	0.25 [4 applications] 0.5 [3 applications] 1.0 [3 applications] 2.0 [3 applications]	No delay to 10
Snapdragon	0.125 [4 applications]	1	0.25 [4 applications] 0.5 [4 applications]	No delay to 2
Sweet Potato Vine	0.125 [3 applications] 0.25 [3 applications] 0.5 [3 applications] 1.0 [2 applications]	N/A	0.25 [4 applications] 0.5 [3 applications] 1.0 [3 applications] 2.0 [3 applications]	N/A
Verbena	1.0 [3 applications]	No delay	1.0 [3 applications]	No delay
Wave Petunia	1.0 [5 applications]	8	1.0 [6 applications] 2.0 [6 applications]	4 to 7

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Micro Drench Trials

Our objective was to determine if multiple, early, and low rate plant PGR substrate micro drenches of uniconazole or paclobutrazol can cost effectively control stem elongation of aggressive annual and perennial bedding plants. Plug and liner trays of *Angelonia* 'Alonia Big Blue', *Calibrachoa* 'Kabloom Pink Blast', *Dianthus* 'Rockin Red', hardy hibiscus 'Summerific Berry Awesome', New Guinea impatiens 'Bounce Cherry Impatiens', sweet potato vine 'Sidekick Black', *Petunia* 'Surfinia Sumo Pink', snapdragon 'Solstice Yellow', *Verbena* 'EnduraScape Red', and *Petunia* 'Wave Carmine' were received and placed in greenhouses at the Plant Science Research Greenhouses at Michigan State University.

Plants were grown at an average daily temperature of 68°F, daily light integral of 10 to 12 mol·m^{-2}·d^{-1}, and under a 16-hour photoperiod from high-pressure sodium lamps. Young plants were transplanted into 5-inch, 6-inch, or 2-gallon containers filled with a commercial soilless substrate composed of 70% peat moss, 21% perlite, and 9% vermiculite. Five to six days after transplant, a substrate drench containing 0.25, 0.50, 1, or 2 ppm paclobutrazol (Piccolo; Fine Americas, Inc.), or 0.125, 0.25, 0.50, or 1 ppm uniconazole (Concise; Fine Americas, Inc.), or reverse osmosis water (untreated control) was applied at a volume of 3 or 4 fluid ounces per 5-inch or 6-inch container, respectively. Plants were fertilized with 125 ppm nitrogen from a feed at each irrigation.

Height measurements of angelonia, dianthus, New Guinea impatiens, lantana, petunia, hibiscus, and snapdragon or the length of the longest verbena, sweet potato vine, and Wave petunia stem were recorded weekly and graphically tracked to assist with subsequent PGR micro drench applications.

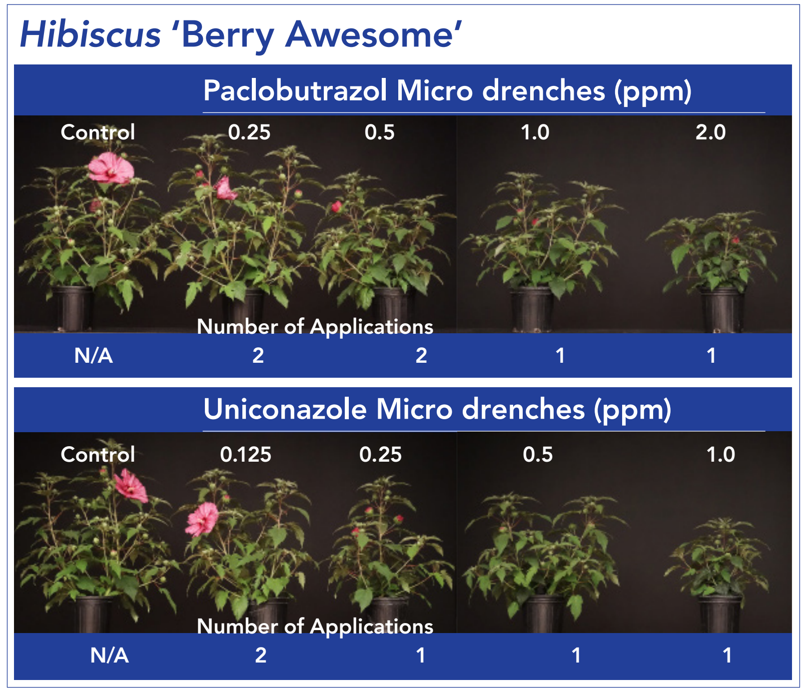

Figure 2: **Effect of paclobutrazol and uniconazole micro drenches on hardy hibiscus.**

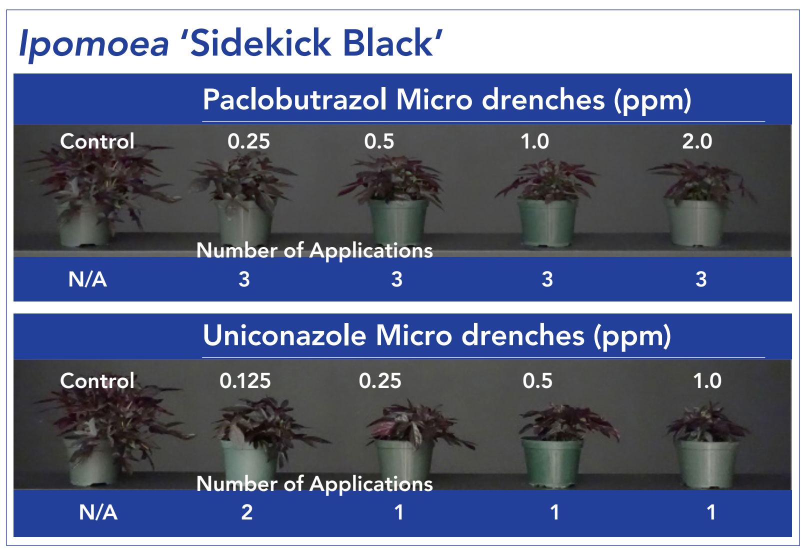

Figure 3: **Effect of paclobutrazol and uniconazole micro drenches on sweet potato vine (Ipomoea).**

What We Learned

Generally, three micro drench applications of paclobutrazol at 0.5 to 1 ppm were effective at controlling angelonia, dianthus, perennial hibiscus, sweet potato vine, lantana, and upright petunia. Time to flower was either not delayed or delayed by up to 10 days depending on the crop (Figures 1 and 2). With the exception of angelonia, two to three micro drench applications of uniconazole at 0.125 to 0.25 ppm were effective for these same crops (Figures 1 to 3). With uniconazole micro drenches, time to flower was either not delayed or delayed up to 12 days (Table 2). Higher rates of paclobutrazol or uniconazole or additional applications at 0.5 to 1 ppm (paclobutrazol) or 0.5 to 1 ppm (uniconazole), might be effective for aggressive cultivars of verbena and petunia. We found that the rates and frequency we used were excessive on the New Guinea impatiens cultivar we tested.

As with any new PGR application method, we recommend you conduct small trials with micro drenches before implementing on a large scale. Effective rates were determined under March to May greenhouse conditions in a northern latitude. Therefore, higher rates or more applications may be necessary in southern locations. **GG**

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Enhancing Your PGR Applications

PART 1

BY KELLIE WALTERS AND ROBERTO G. LOPEZ

How does spray water alkalinity affect the efficacy of commonly used plant growth regulators?

Do you plan to use plant growth regulators or retardants (PGRs) on your spring crops? Did you know that the pH of the spray solution and air temperature at application can influence the efficacy of some PGRs? In this two-part series, we will show you how to save time and money, by monitoring and adjusting two often overlooked cultural and environmental factors that can influence PGR efficacy.

In order to increase plant densities, meet market or buyer specifications, and produce compact and aesthetically pleasing plants, greenhouse growers use a wide variety of PGRs. Many factors influence PGR efficacy including the active ingredient, use of surfactants, chemical concentration and volume applied, solution pH, and environmental conditions (such as humidity, air movement, light and temperature at application).

In this article, we will focus on how spray water alkalinity affects the efficacy of three commonly used PGRs. In the next article, we will discuss how to manage air temperatures to maximize PGR spray results.

GA BIOSYNTHESIS INHIBITORS

The most commonly used PGRs are the gibberellin inhibitors (also referred to as gibberellic acid or GA). These PGRs control extension growth (i.e., plant height) by inhibiting various steps in the biosynthetic pathway of gibberellins, the plant hormone responsible for cell elongation. Plant growth retardants with active ingredients of ancymidol (i.e., A-Rest or Abide), chlormequat chloride (i.e., Cycocel, Citadel, or Chlormequat E-Pro), daminozide (i.e., B-nine or Dazide), flurprimidol (i.e., Topflor), paclobutrazol (i.e., Bonzi, Piccolo, Paczol or Downsize), or uniconazole (i.e., Sumagic or Concise) are all GA inhibitors.

OTHER PGRS

The PGRs Fascination and Fresco contain two forms of GA (GA_4 and GA_7) plus the synthetic cytokinin benzyladenine (BA). These PGRs are used to counteract over application of one of the previously mentioned GA inhibitors or suppress lower leaf yellowing.

Another PGR, ethephon [i.e., Florel (3.9 percent active ingredient) or Collate (21.7 percent active ingredient)] can also be used to inhibit stem elongation, abort flower buds and flowers, and promote lateral branching. Ethephon [(2-chloroethyl) phosphonic acid] is a compound that breaks down to release the gas ethylene. This PGR is only labeled for spray applications, although research shows that it can also be effective as a drench.

ALKALINITY AND PH

The pH of the carrier water used to mix many of the chemicals used in agriculture can influence their efficacy. One example we should all be familiar with is ethephon. As ethephon is mixed with carrier water to make a spray solution, it converts into the gaseous and active form ethylene. At a low pH (4.5 or below), ethephon is stable and ethylene is not released. As pH increases, ethephon breaks down into ethylene more quickly. Therefore, the goal is to keep it in the liquid form until it is inside the plant.

One way to keep ethephon in its liquid form longer is to manage the pH of the solution. Therefore, the goal for ethephon sprays is to keep the solution pH below 4.5. Ethephon is naturally acidic, so this is normally not a problem. However, if the carrier water has a high alkalinity ($CaCO_3$), the pH may not decrease enough to fall below 4.5. Once the chemical is absorbed by the plant, the plant's more neutral pH will cause the ethephon to change to ethylene. Additionally, the recommended spray solution pH for uniconazole and GA_{4+7}/BA spray solutions is 5.5 to 6.5.

THE STUDY

We conducted a series of experiments to investigate how carrier water alkalinity affects the efficacy of ethephon, uniconazole, and GA_{4+7}/BA spray solutions applied to various greenhouse crops. In all of the experiments, we adjusted the Michigan State University (MSU) greenhouse tap (carrier water) water to 50-, 150-, or 300- ppm $CaCO_3$ by adding sulfuric acid. Alkalinity was measured by using a Hanna Alkalinity Colorimeter (Figure 1).

Ethephon. The adjusted carrier water (50-, 150- and 300-ppm $CaCO_3$) was mixed with ethephon (Collate, Fine Americas) to create 0-, 250-, 500- and 750-ppm ethephon solutions. Rooted cuttings of verbena 'Aztec Blue Velvet' and ivy geranium 'Precision Pink', and plugs of petunia 'Easy Wave Neon Rose' were transplanted into 4-inch containers. Once roots reached the sides of the containers, the plants were sprayed 14 and 23 days after transplant. For the second replication of the study, rooted cuttings of New Guinea impatiens 'Clockwork Purple' and zonal geranium 'Fantasia Pink' along with

Figure 1. Alkalinity meters make it easy to check your carrier water alkalinity in house.

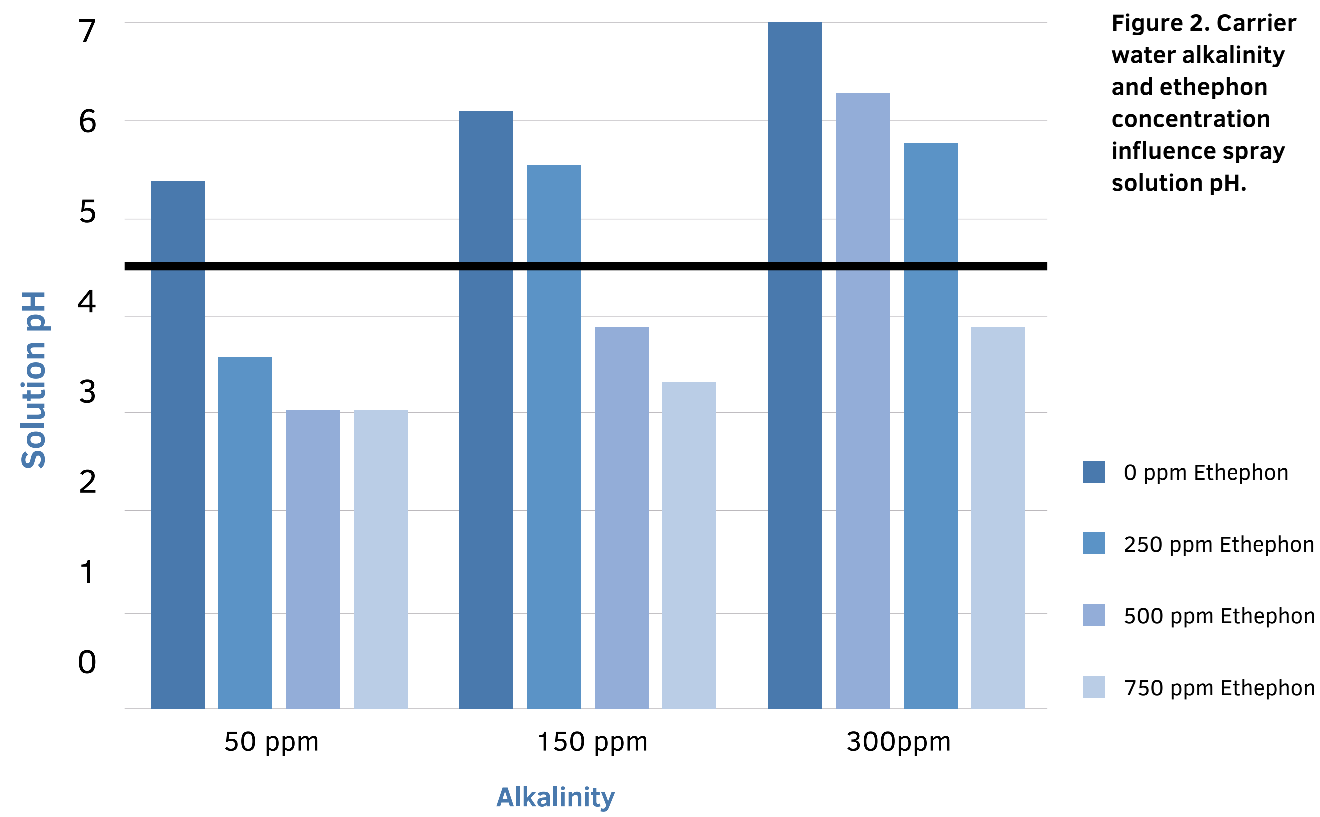

Figure 2. Carrier water alkalinity and ethephon concentration influence spray solution pH.

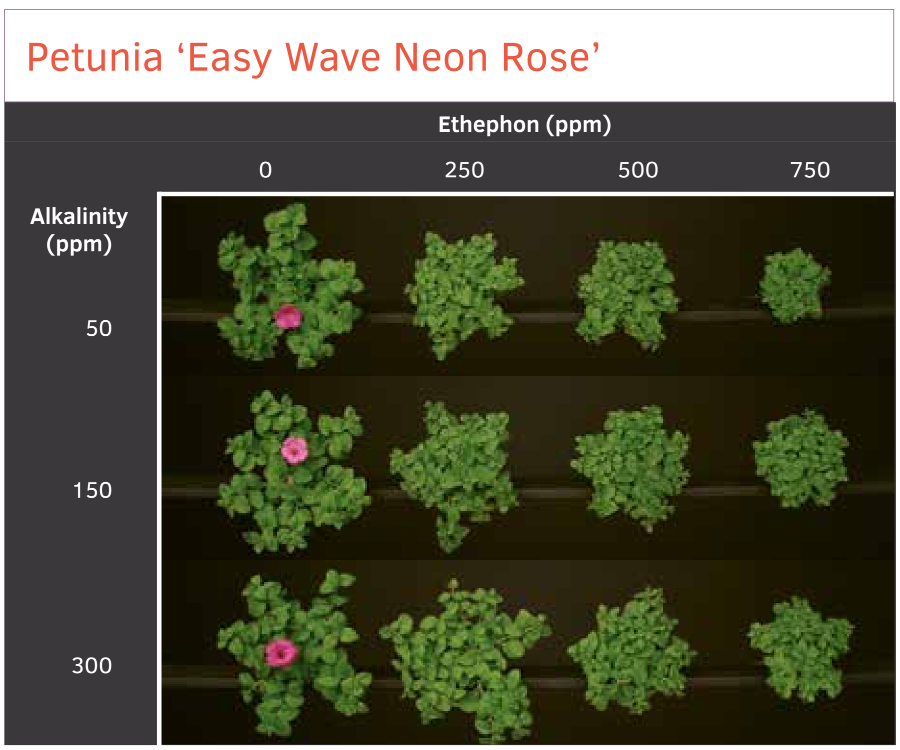

Figure 3. Petunia 'Easy Wave Neon Rose' sprayed with 0-, 250-, 500- or 750-ppm ethephon with carrier water alkalinities of 50-, 150- or 300-ppm $CaCO_3$ four weeks after transplant.

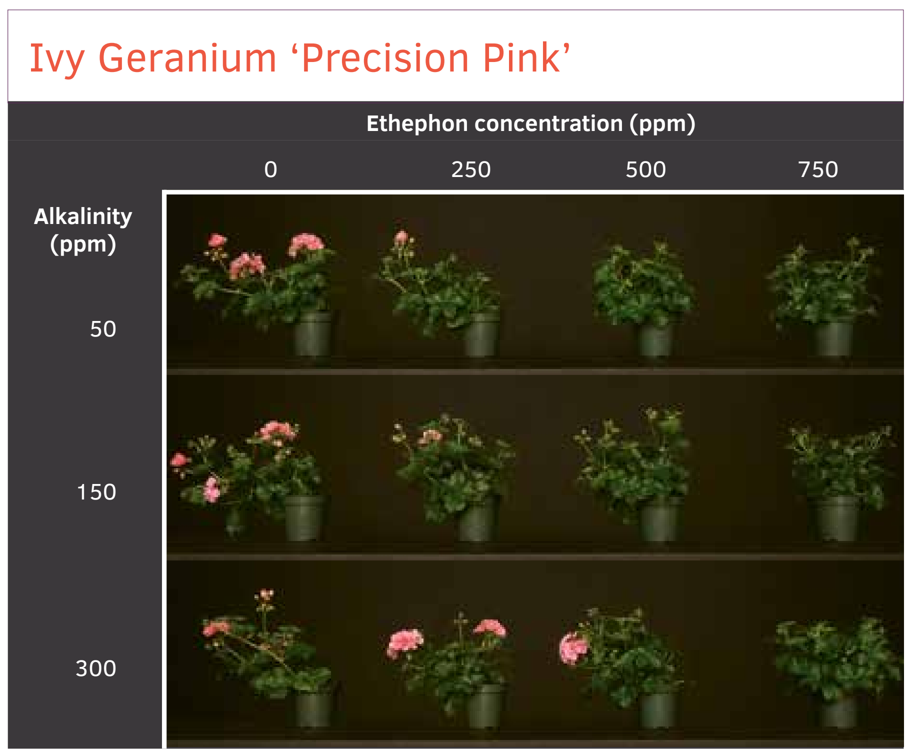

Figure 4. Ivy geranium 'Precision Pink' sprayed with 0-, 250-, 500- or 750-ppm ethephon with carrier water alkalinities of 50-, 150- or 300-ppm $CaCO_3$ eight weeks after transplant.

verbena, ivy geranium and petunia were sprayed with the same ethephon solutions seven, 10 or 14 days after transplant depending on species and when the roots reached the edge of the container.

Uniconazole. The adjusted carrier water (50-, 150- or 300-ppm $CaCO_3$) was mixed with uniconazole (Concise, Fine Americas) to create 0-, 7.5, 15-, or 30-ppm uniconazole solutions. Plants from the five species previously mentioned were sprayed 14 days after transplant.

GA_{4+7}/BA. Plants were sprayed 14 days after transplant with a solution containing 30-ppm uniconazole (carrier water alkalinity of 150-ppm $CaCO_3$). Twenty-one days after the uniconazole spray, the plants were sprayed with a solution containing 0-, 1/1-, 5/5- or 10/10-ppm GA_{4+7}/BA (Fresco, Fine Americas) with carrier water alkalinities of 50-, 150- or 300-ppm $CaCO_3$.

WHAT DID WE LEARN ABOUT PH?

Ethephon itself is acidic; therefore, as you increase the ethephon concentration, the solution pH decreases. Additionally, as your carrier water alkalinity decreases, your solution pH decreases (Figure 2). The addition of uniconazole or GA_{4+7}/BA to the carrier water did not significantly affect the solution pH. Therefore, carrier water pH can be changed and adjusted without having to account for a change in pH.

HOW DOES CARRIER WATER ALKALINITY INFLUENCE PGR EFFICACY?

We determined that there was an interaction between carrier water alkalinity and ethephon concentration (Figures 3 and 4). Understanding this interaction can help you maximize spray efficacy and potentially reduce PGR rates or the number of applications. For example, a grower in the Midwest may have carrier water with an alkalinity of 300-ppm $CaCO_3$. They decide to spray their petunia crop with 500-ppm ethephon. If they reduce the alkalinity of their carrier water to 50-ppm $CaCO_3$, they can significantly reduce extension growth (Figure 4). Alternatively, if the grower was happy with the results provided by the combination of 300-ppm $CaCO_3$ and 500-ppm ethephon, they could cut the ethephon rate in half if they reduced the carrier water alkalinity to 50-ppm $CaCO_3$ (Figure 4). To determine the alkalinity of your carrier water, simply send water samples to a lab or use a hand-held meter (Figure 1).

Increasing concentrations of uniconazole reduced the height of zonal geranium while increasing GA_{4+7}/BA increased the stem length of verbena. Efficacy of uniconazole and GA_{4+7}/BA on these two crops was slightly reduced with increased carrier water alkalinity, but the reduction was not commercially significant. The uniconazole rates used in the study were effective in controlling the growth of New Guinea impatiens, petunia, and verbena, while GA_{4+7}/ BA sprays resulted in increased extension growth of petunia, New Guinea impatiens and verbena, and their efficacy was not affected by spray water alkalinity.

TAKE HOME MESSAGE

If you use ethephon, we recommend that you check the alkalinity of your carrier water before mixing. This can be done by sending a water sample to your preferred lab or testing your carrier water with a hand-held alkalinity meter (Figure 1). If your carrier water alkalinity is too high, you may need to add a buffering agent such as an acid (i.e., sulfuric acid) or adjuvant (i.e., pHase5 or Indicate 5) to lower the alkalinity and final solution pH. Next, add ethephon and check the pH of your spray solution with a hand-held pH meter to ensure that it is below 4.5. Carrier water alkalinity does not appear to have a large effect on uniconazole nor GA/BA sprays.

As always, perform in-house trials to evaluate the effectiveness of PGRs on plants produced under your growing conditions. gpn

Kellie Walters is a PhD student and Roberto G. Lopez is assistant professor and controlled environment/ floriculture Extension specialist in the department of horticulture at Michigan State University. *The authors gratefully acknowledge Fine Americas Inc. for chemicals and funding, the Western Michigan Greenhouse Association and the Metropolitan Detroit Flower Growers Association for funding, Ball Horticultural Co. for plant material, and Nathan DuRussel and Anthony Soster for greenhouse assistance.*

Branching Out with PGRs

PGRs can be used for more than just reducing stem elongation. Here, we'll explore PGRs that induce lateral branching on crops that don't branch freely.

Roberto Lopez

Did you know that plant growth regulators (PGRs) have many applications, including suppressing or promoting stem elongation, preventing lower leaf yellowing, increasing branching and rooting, promoting or inhibiting flowering? Most plant growth retardants that inhibit the synthesis of plant hormones (i.e., Gibberellins [GA]) are PGRs used to suppress extension growth (i.e., plant height) of crops to keep them compact. Plant growth retardants with active ingredients of ancymidol (Abide or A-Rest), chlormequat chloride (Altercel or Citadel), daminozide (B-Nine or Dazide), flurprimidol (Topflor), paclobutrozol (Bonzi, Piccolo, Piccolo 10XC, Pac O or Downsize), or uniconazole (Sumagic or Concise) are all GA inhibitors.

However, PGRs that commonly contain synthetic plant hormones that promote lateral branching, rooting, promote or inhibit flowering, or inhibit leaf yellowing are called plant growth regulators. PGRs that enhance branching (branching agents) include active ingredients such as ethephon (Collate 2L and Florel), benzyladenine (BA; Configure) or dikegulac sodium (Atrimmec).

How do these branching PGRs work? Most branching agents promote lateral branching by releasing/interrupting apical dominance and therefore cause lateral axillary buds to break.

How each product works

Plants produce the hormone cytokinin to regulate growth, cell division and even leaf senescence. Synthetic cytokinins such as benzyladenine (BA), thidiazuron and kinetin have been developed for plant applications. The PGR Configure contains 2.0% 6-benzylaminopurine (6-BA) alone and is used to increase lateral branching and promote flowering in certain ornamental species. Additionally, on some crops Configure can reduce stem elongation and result in more compact and well-branched plants. Whereas the PGRs Fascination and Fresco contain 1.8% 6-BA and 1.8% gibberellins A4 and A7 (GA4+7). These BA + GA4+7 products are commonly used to prevent lower leaf yellowing on Easter, LA Hybrid and Oriental lilies and geranium cuttings, and to promote poinsettia bract expansion and stem elongation when plants receive an excessive amount of PGR (i.e., plant growth retardant). Additionally, the combination of both hormones provides synergistic and controlled growth by stimulating internode elongation and axillary shoot growth.

Fresco can be applied via foliar spray, media drench or chemigation, while Fascination is only labelled for spray applications. As a gaseous plant hormone, ethylene is known for its role in senescence and fruit ripening. The PGR Collate 2L contains 21.7% and Florel contains 3.9% ethephon [(2-chloroethyl) phosphonic acid]. As a liquid, ethephon breaks down to release ethylene as a gas. Both products are used to inhibit internode elongation, hinder apical dominance, and thus increase lateral branching and abort flower buds and flowers. Currently, both products are only labelled for spray applications. Pending regulatory approval, Collate 2L could be labelled for drench application in 2024.

Lastly, Crest is a product that Fine Americas had on the market until recently. It contained the following 0.010% cytokinin (as Kinetin), 0.005% Indole Butyric Acid (IBA) and 0.005% Gibberellic Acid (GA3). It was labelled for use as a foliar spray or sprench to reduce apical dominance and to promote bud differentiation, cell division, root induction and growth. Configure, Collate, Florel, Fresco and Fascination are labeled for greenhouse use on floriculture crops. Most PGRs have flexible-use options based on their "experimental" use label. This will enable you to legally utilize PGRs on floriculture crops grown in a greenhouse.

While much research with branching PGRs has focused on perennials, many annuals, including new cultivars and genera, could benefit from PGRs to improve their growth habit and fill in their containers. In this study, we examined the use of branching agent PGRs alone or in combination with other PGRs to see if they synergistically lead to compact and well-branched flowering annuals and perennials and sedges without negatively affecting flowering or causing phytotoxicity.

The study

Rooted liners of Angelonia Big Indigo, Calylophus Ladybird Sunglow, Papyrus King Tut, Lantana Santana Red Orange, Petunia Night Sky, Ivy Geranium Light Lavender, Russian sage Sage Advice, and *Verbena rigida* Cake Pops were transplanted in 4.5-in., 6-in. or 1-gal. trade pots. After two weeks they received one of the following 13 spray treatments: no spray (control); Configure at 200, 400 or 800 ppm; Fresco at 4, 8 or 12 ppm; Crest at 20, 30 or 40 mg per liter; Configure at 200 ppm + Crest at 20 $mL \cdot L^{-2}$; Fresco at 4 ppm + Configure at 200 ppm; or Collate at 250 ppm + Crest at 20 $mL \cdot L^{-2}$. Not surprisingly, the different crops responded differently to the PGRs.

A single spray application of Configure at 400 ppm resulted in angelonia, calylophus, geranium, petunia and Russian sage producing 10, 43, 4, 26 and 82 more branches than the untreated control (Figures 1, 2, and 3). With the exception of Russian sage, all the other crops were much more compact and flowering was delayed compared to the control.

Generally, 800 ppm of Configure resulted in very-well branched, but stunted plants that flowered two to four weeks later than the control. Angelonia, calylophus, petunia, ivy geranium, verbena and Russia sage treated with Fresco at 4 to 8 ppm produced four to eight, 16 to 34, seven, four to five, six, and nine more branches, respectively, than the control (Figures 1 to 3) .

Overall, the plants' height was similar to the control and little to no delay in flowering was observed. Crest was effective at rates of 20 to 40 mL•L^{-2} on angelonia, petunia, Russian sage and papyrus (Figures 1 and 3). A combination of Configure at 200 ppm and Crest at 20 mL•L^{-2} promoted branching on petunia and ivy geranium (Figure 3). Angelonia, calylophus, petunia and ivy geranium receiving a spray application of Fresco at 4 ppm + Configure at 200 ppm developed four, 22, seven and three more branches than the control (Figures 1, 2 and 3). Flowering of calylophus and ivy geranium was delayed with this combination. Lastly, 250 ppm of Configure + 20 mL•L^{-2} of Crest resulted increased branching for angelonia, calylophus, cyperus, ivy geranium and Russian sage (Figures 1 and 2).

The collective results of this study indicate that PGRs can be effectively used to increase branching, and in some cases, reduce stem elongation to produce higher-quality crops.

Tips

- 6-BA doesn't readily move within the plant; therefore, complete coverage is required.
- 6-BA can significantly delay flowering of gaillardia.
- Avoid rates of 10 ppm or higher of BA + GA4+7 products, as it can lead to excessive plant stretch.
- Only apply ethephon when plants are actively growing and not drought or heat stressed.
- The efficacy of ethephon is influenced by the pH of spray solution (ethephon + water) and the air temperature at application. Therefore, ensure the pH of the solution is 4.5 to 5.0 and the temperature at application and 24 hours later is <70F (21C).

For more information about PGRs and annual bedding plants, refer to the 2023-24 Plant Growth Regulators Guide for Annuals by Brian Whipker, North Carolina State University. For perennials, refer to the 2024-25 Growth Regulators for Containerized Herbaceous Perennial Plants guide by Garrett Owen, The Ohio State University.

Need help mixing PGRs? The PGRMix Master created by e-GRO (Electronic Grower Resources Online), a collaborative effort of floriculture specialists, and Fine-Americas, Inc. can assist you in mastering all your PGR needs.

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Roberto Lopez is an Associate Professor and Controlled Environment/Floriculture Extension Specialist.

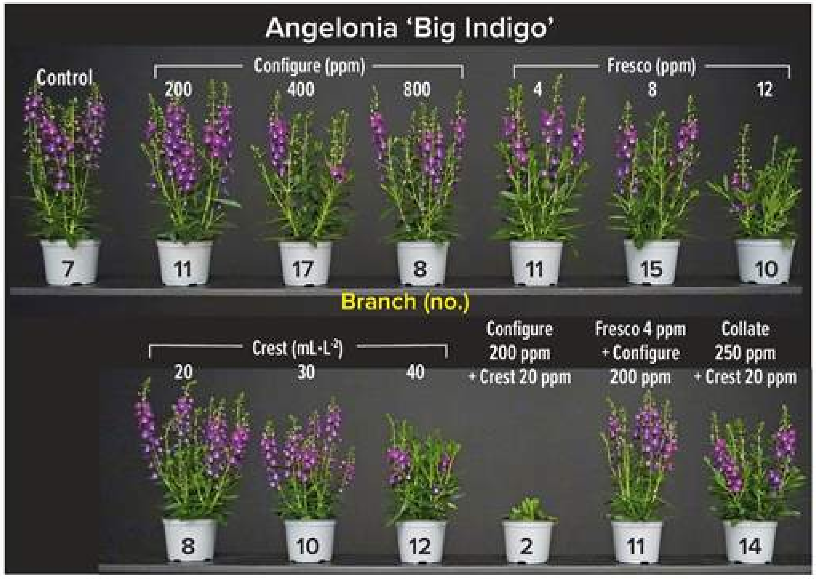

Figure 1. Growth and flowering responses of Angelonia Big Indigo sprayed with different PGRs two weeks after transplant.

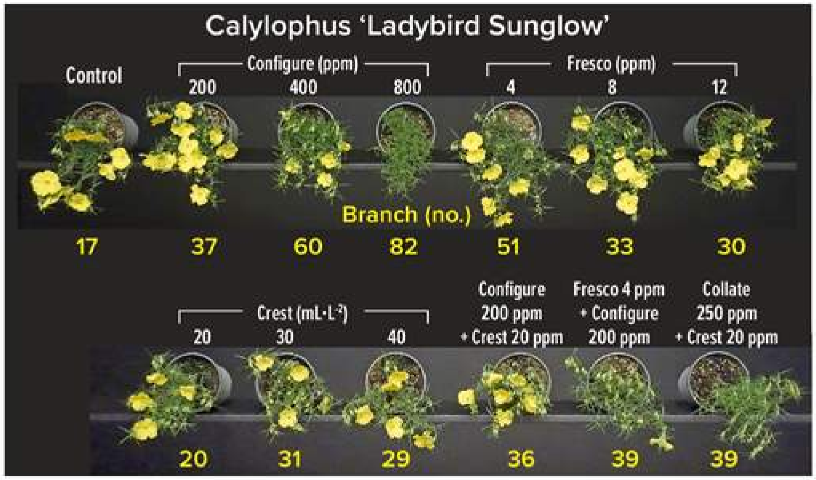

Figure 2. Growth and flowering responses of Calylophus Ladybird Sunglow sprayed with different PGRs two weeks after transplant.

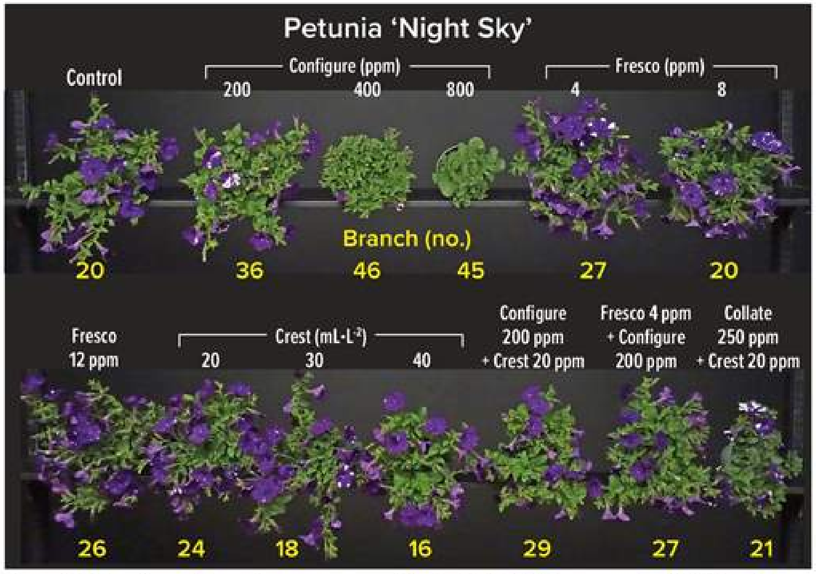

Figure 3. Growth and flowering responses of Petunia Night Sky sprayed with different PGRs two weeks after transplant.