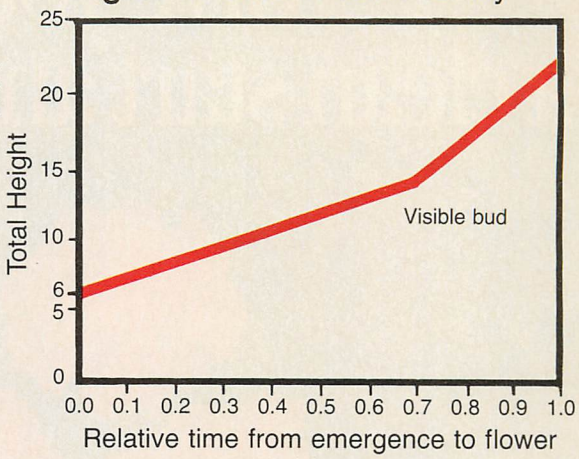
Figure 1. The lily growth curve is a straight line until visible bud, followed by a steeper straight line. Growth curves for chrysanthemums and poinsettias are similar, showing a sigmoid (S-Shaped) pattern of development where plants reach 60 percent of final height in half the time to flower.

Figure 1. Growth curve for lily



Get the plant height you want with graphical tracking

Growing uniform lilies, poinsettias and mums on time isn't hocus pocus. By measuring your plants and making a graph, you can take the guesswork out of growing and put a little more black on your bottom line.

by William H. Carlson and Royal Heins

An experienced grower is hard to replace. Years of experience, knowledge, mental notes and information combine to produce that legendary "green thumb" that tells how and when to do what in order to bring in a quality crop on time. When we were starting out, a seasoned old grower advised us the key to success was keeping one hand on the ventilator and the other on the watering hose.

His advice was basically right—then it truly was an art. Today, with the use of computers and mathematics, growing is becoming more of a science. One of these sciences is a predictive technique called "graphical tracking," which is a procedure where actual plant development is plotted against expected development.

The key components of graphical tracking are: 1) predicting desired plant height during development; 2) measuring actual height and plotting this information on a graph to compare with desired height; 3) adjusting temperatures and/or applying growth regulators to reduce the difference between actual and desired plant height at any time in plant development.

Predicting desired plant height

From our graduate student studies we developed stem elongation developmental curves for lilies, poinsettias and chrysanthemums. The growth curves for poinsettias and chrysanthemums are similar; there is a different curve for lilies (Figure 1). The lily curve is a straight line until visible bud and then a steeper straight line until flowering. At visible bud the lily is approximately one-half its final height. On the other hand, the growth curve for poinsettia and chrysanthemum is a sigmoid curve with the plant attaining 60 percent of its height in half the time to flower.

The window for lilies

Let's first discuss how to make a "tracking window." This window represents the height where your plants should be at any time from emergence to flower if they are to bloom at a desired height. If their measurements do not fall in the tracking window, adjust their development by using temperature changes or growth regulator applications.

To construct the tracking window graph for lilies, draw a graph like the one shown in Figure 2 with height up the side and days to flower across the bottom. Let's assume you need lilies ready for shipment by April 1, and your

Figure 2. Easter lily graph.

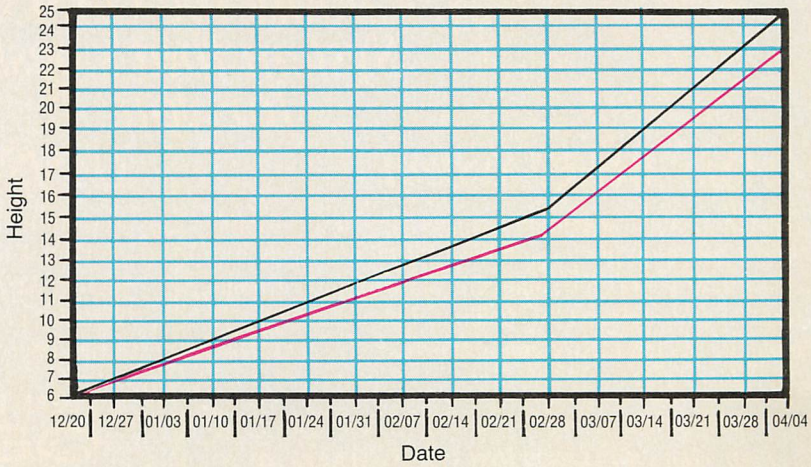
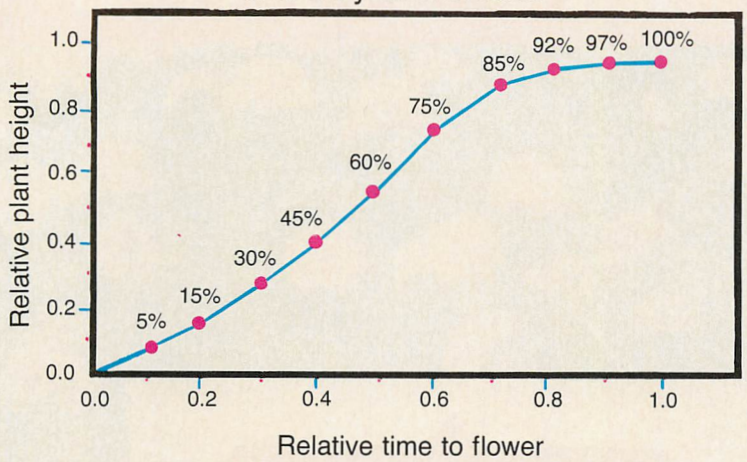


Figure 2. For Easter lilies, construct a tracking window—the area between the two lines—that represents the height where your plants should be at any time from emergence to flower, if they are to bloom at a certain height. If plant measurements don't fall within the windows, adjust development with temperature changes or growth regulators.

Figure 1. Growth curve for poinsettia and chrysanthemum.



final desired lily height is 22 to 24 inches. (Subtract 6 inches for the pot, leaving 16 to 18 inches actual height.)

We know from experience that a lily typically doubles in height from visible bud to flower, so visible bud height should be 50 percent of final height or 8 to 9 inches (14 to 15 inches including the pot). Connect beginning height (6-inch pot plus zero-inch plant) with these desired minimum and maximum heights at visible bud and flower to form your tracking window.

ing, it should be between 9.5 and 10 inches tall on the third week (that includes the pot and plant).

There are three phases of growth for poinsettias and chrysanthemums: the lag phase, the rapid growth phase and the plateau phase (Figure 3). With most of the pinched plants we've studied, there is usually about a two-week period immediately after the pinch referred to as the lag phase. A period of rapid growth follows where 70 percent of growth occurs in 50 percent of the

Figure 3. Growth phases.

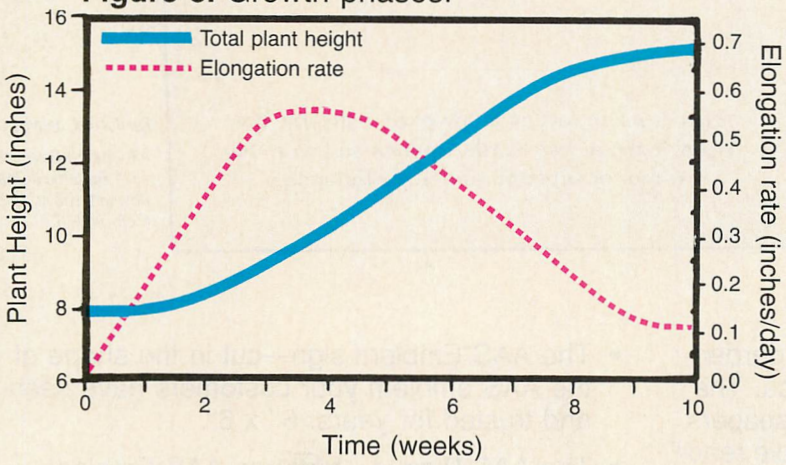


Figure 3. Growth curves for poinsettias and chrysanthemums show three growth phases: lag, rapid growth and plateau. The lag phase occurs in the two weeks after pinching. Next, 70 percent of growth takes place in the rapid growth phase. Only 15 percent of growth is in the plateau phase. Best height control opportunities are during the rapid growth phase.

Mum and poinsettia curves

For poinsettia and chrysanthemum, Figure 1 shows percent of plant height that should develop relative to time to flower. For example, if we have a variety that takes 10 weeks from pinch to flower, 5 percent of growth should occur by the end of Week 1, 15 percent by the end of Week 2, 30 percent by the end of Week 3, and so forth. Therefore, if you want a poinsettia with a total height of 15 to 17 inches at flower-

development time. In the last 25 percent of the time (the plateau phase), only 16 percent of total growth occurs.

Height control is most effective when plants are actively growing. Therefore, if you are aware of this growth curve, you can begin to see that height control, either by temperature or chemical means, works best in the rapid growth phase. So, methods to control height on these two species are best done from Week 2 to Week 7. Using height control

Figure 4. The DIF concept.

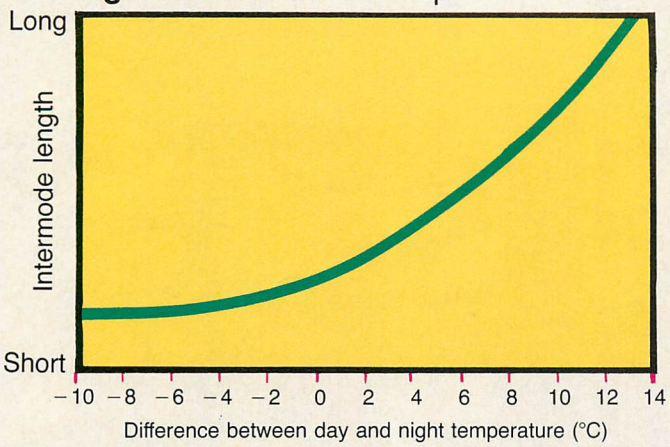


Figure 4. The difference between day and night temperatures (DIF) is one tool that can be used to control plant height. A positive DIF means taller plants.

measures in the first two weeks or the last weeks of these crops has less effect than a similar treatment during rapid elongation.

How-tos of graphical tracking

After you develop the graph, the goal is to keep plant height inside the window that is within those two lines on the graph. Typically growers measure plants twice a week during the rapid growth phase. In the lag or plateau phase, measure less often.

While the ideal situation is to have all plants the same height, in reality the height of a population will vary. You might have to measure the height of several tall plants, several short plants and several average plants and plot each group out. Once this is done, you must make a management decision.

If all poinsettias must be 18 to 21 inches without exception, you might have to sort the crop—grouping similar size plants—and grow each group under different temperatures to bring them all in at the same height. Or you may wish to hand spray the tall plants with a growth regulator to even the crop out, or you may live with the ununi-

formity and find a special market with the taller or shorter plants. The right procedure depends on your market and your production systems.

Tools for height control

Growth regulators and temperature manipulations are the tools presently used to control height. Growth retardants reduce further stem elongation. Apply them early in the rapid growth phase for maximum impact. If applied late in the rapid growth phase or in the plateau phase, they'll have little effect on plant growth and may produce disadvantages like smaller flower size or a delay in flowering.

Figure 5. Tools for poinsettia height control.

Growth Period	Temperature	Growth Regulators
Before pinch (Sept. 10)	Yes, if possible	Yes, if needed
Pinch to initiation	Yes, if possible	Yes, if needed
During initiation (Sept. 20 to Oct. 5)	Yes, if possible	Yes
Initiation to Oct. 15	Yes	Yes
Oct. 15 to Nov. 15	Yes	Not desirable
Nov. 15 to sale	Yes, minimal effect	Not desirable

Dates are based on growing poinsettias in the upper Midwest. Dates may be later in warmer southern locations.

Use temperature to increase plant height or reduce stem elongation. Stem elongation is influenced differently by day and night temperature. In general, stem elongation rate and plant height both increase as day temperature increases and decrease as night temperature increases.

More importantly, the difference (DIF) between night and day temperature influences stem elongation and plant height (Figure 4). Plants grown with a positive DIF (warm days and cool nights) are taller than plants grown with a negative DIF (cool days and warm nights). Plants grown with different day and night temperatures but with the same DIF elongate similarly.

The response to DIF is quantitative, that is, the more positive the value of DIF, the greater the amount of stem elongation. It is important to know the magnitude of response to a change in DIF is not the same across all values of DIF.

For example, reducing DIF from a positive value (say, plus 5 degrees) to zero reduces elongation more than reducing DIF from zero to negative value (minus 5 degrees). Therefore, if you only change your temperature regime from warm days and cool nights to equal day

and night temperatures, you will have a significant reduction in plant height.

Make the windows work for you

Once you have developed a graph, measure your poinsettia plants and plot measurements on the graph twice a week. If the poinsettia is in the window, use the same temperatures and no growth retardant until the next week.

One advantage of plotting plant height on a regular basis is that you can see how much plants have elongated since the last measurement and by extrapolation, estimate how tall plants will be by the next measurement. It is possible to measure plants and find their heights fall within the tracking window. Extrapolation, however, may show plant height will exceed window height by the next measurement if plants continue to grow at their current growth rate. With this knowledge, you can act before plants become too tall, not react to a taller than desired plant. The actions available include changing DIF, applying a growth retardant or both.

After making adjustments, measure plants twice a week. If they are in the window, no growth retardant is needed and temperatures can be adjusted to achieve the required height. For example, if plants are in the window, an equal day and night temperature may be adequate for growth required. If the plants become too short, then a positive DIF temperature is required; if plants are too tall, try a negative DIF.

Figure 4 shows the relationship between internode length and temperature, as well as the relationship between plant height, elongation rate and time. There is very little decrease in height between minus 4 and minus 10 degrees DIF. In fact, even at zero degrees DIF, the same day and night temperatures get about 70 percent of the plant height reduction. However, if you increase to a positive DIF, the plant immediately starts to elongate and at a very rapid rate. Even a positive 5-degree DIF starts to produce tall plants. Use this chart to predict the increase one might expect.

Using the tools of temperature DIF and growth retardants and following the graphical tracking system, it is then merely a matter of staying in the window and aiming to the final height when plants are needed. It will certainly take the guesswork out of producing the proper plant height.

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