The information herein was originally published in *Greenhouse Product News,* 12(5): 8-14, 2002.

Height Control and the Use of Plant Growth Regulators on Spring Bulbs

William B. Miller
Flowerbulb Research Program
Department of Horticulture
Cornell University
Ithaca NY 14853
wbm8@cornell.edu

Flowerbulbs comprise a significant proportion of the spring production of many North American greenhouses. Their quick greenhouse time, close spacing, and generally "green" reputation (little fertilization required, limited pest problems) are all attractive to growers. In North America, many of the crops and cultivars are too tall when grown in 4" or 6" pots, and this is one of the issues we are addressing in the program.

In many cases, the real issue for growth regulation for spring bulbs is not height control during production. Instead, control of unwanted growth in the postharvest chain (retail and end-user phases) is of paramount importance. This is clearly seen in Figure 1, showing the miniature 'Tête-à-Tête' daffodil as it appears during marketing, and after 7 days in a typical interior (consumer) environment at 70F. Similar exuberant growth is seen in many hyacinth cultivars. Thus, spring bulb growth regulation is often a case of PGR application in the greenhouse for growth control in the low light and rather warm interior environment.

Factors Affecting Height in Spring Bulbs

Cultivar. Effective height management in bulb crops relies first on proper cultivar selection. Most tulips were originally selected for use as cut flowers. Therefore, for effective use as pots, PGRs are generally needed. There is a constant (and increasing) stream of new tulip cultivars being introduced from breeding programs in Holland, and there is increasing emphasis on cultivars adapted to pot culture without the need for PGR's. Until growers become familiar with newer cultivars, however, PGR use will continue. Across the range of bulb genera, there are numerous other examples of smaller cultivars available for pot forcing: dwarf lilies, dahlias, daffodils, and amaryllis are but a few.

Length of cold. Tulips, daffodils, and hyacinths all share a common characteristic: the longer the length of cooling (and rooting) before forcing, the taller the plant ultimately will be. For example, Figure 2 shows 6" pots of the cultivar 'Pinocchio' (a Greigii tulip) given 17 or 22

weeks of cold and forced in the greenhouse. The extra elongation from the longer cold period is clearly seen. Therefore, simply giving the correct cold period by not exposing plants to excessive lengths of cold can achieve a significant degree of height control. The obvious problem here is that growers want to plant their entire bulb crop at one time and be done with it. While efficient at the start, this method leads to excessive height and possible lost quality for the last crops of the year. To cool bulbs to the proper length would require bulbs to be delivered at differing times, or for proper temperatures to be delivered to the bulbs at each grower's facility. Labor scheduling can be an issue as well.

Temperature. Generally speaking, warmer forcing temperatures promote greater overall elongation of bulb crops. A good example can be seen in pot freesia, where George Wulster showed that increasing temperature from 50F to 68F doubled plant height.

Plant Growth Regulators

With most spring bulbs, the primary PGR application is by "soil" (media) drench. This is especially true for tulip, and to date the major products used have been ancymidol (A-Rest) and paclobutrazole (Bonzi). Hyacinths and daffodils are an exception, and foliar sprays with ethephon (Florel) are the standard treatments used. While an important product for Easter and hybrid lilies, Sumagic has not emerged as a major PGR on rooting-room bulb crops even though it is an effective product in many cases.

A few words on media drenches are in order. The optimum drench is one that would completely saturate the media with solution, and allow less than 10% of the applied volume to leach. This is especially true for bulb crops where the vast majority of the roots are in the bottom third of the root ball. Typically, drenches are applied in 2 or 4 ounces of volume for 4" and 6" pots, respectively, and recipes are given in Table 1. To assure even dispersal of the drench solution, the plants should be watered 24 or fewer hours before applying the drench. This will assure an even media moisture content, and will give a uniform distribution of the drench into the pot. Drenching into an overly dry media may lead to unevenness from channeling, or at the very least, less PGR effect as the material may not penetrate to the bottom third of the pot where the roots are.

The rate ranges, products and application methods are given below for the major spring crops. Additionally, the Holland Bulb Forcer's Guide is an important reference for forcing bulbs and the industry owes a great debt of gratitude to Gus de Hertogh for its conception and refinement over the years. It is an essential reference for anyone producing bulbs commercially and is highly recommended. Specific use rates, by cultivar and forcing period can be found there.

Current and Potential Height Control Methods by Crop

Tulip

As stated, a key point is that the longer a tulip is cooled (especially while it is rooted, as in the case of pot tulips), the taller it will be, all other things being equal. Thus, within the confines of labor, facilities and management limitations, avoiding excessive cooling can provide a good degree of height control. A second key point is that growers should

constantly check their crops in the rooting room, and promptly reduce temperatures to 32-33F after all plants are rooted. Reducing temperature reduces shoot elongation in the cooler, and may also help to control unneeded root growth that can lead to problems with the *Trichoderma* fungus. The difference between 32-33F and 40-42F is enormous for bulb stem elongation over a 6-8 week period in the cooler.

Once the above matters are considered, the typical treatment for tulips is to apply a Bonzi or A-Rest drench within 1-2 days of moving into the greenhouse. Rates vary from 0.125-0.5 mg/pot of A-Rest and approximately 0.5-2 mg/pot Bonzi, depending on cultivar and time of year. Delaying the drench will give significantly less growth control as much of the effect of PGRs is concentrated in the bottom internode of the plant. Conversely, Bonzi and Sumagic are both effective in reducing the elongation of the top internode and can provide good height control in the postproduction environment. Some examples of Bonzi effectiveness on three tulip cultivars are given in Figure 3.

Experimentally, pre-plant bulb soaks in Bonzi or Sumagic are effective on tulips. As seen in Figure 4, results can be startlingly effective as with 'Apeldoorn', a vigorous Darwin hybrid cultivar. While not recommended as a pot plant, certain dip treatments are practically capable of tailoring 'Apeldoorn' into a usable 4" plant! Another interesting finding is that even with severe height reduction, there is essentially no delay in flowering, nor any reduction in flower size. Also, we are achieving effective height control by drenching with Bonzi or Sumagic immediately after planting and prior to cooling.

Hyacinth

While most hyacinths flower within the limits of the "aesthetic ratio", the very heavy flower stalks often topple over. As seen in Figure 5, cultivar selection can help avoid this problem. Aside from cultivar, Florel is commonly used for height control in hyacinths, and result in shorter, stockier flower stalks that are more resistant to toppling. The safe window for spraying Florel is short: it should be sprayed when the plants are 3-4" tall, but the flowers must not show full color at spraying. Some cultivars require a second application (2-3 days after the first) to keep the flower stalks sufficiently short; be certain to consider this in relation to the timing of the first spray. If flowers are open, Florel can cause premature senescence, an obviously undesirable situation. Florel should be sprayed to runoff onto well-watered plants. To avoid water on the leaves of flowers at night, a late morning to early afternoon application is recommended. Guidelines for preparation of Florel solutions re given in Table 2.

In our Cornell work, we have been experimenting with bulb dips, and pre- or post-cooling drenches of Bonzi or Sumagic. As seen in Figure 6, Bonzi or Sumagic pre-plant dips were effective in controlling height of prepared 'Anna Marie' hyacinths. IN these experiments, you can see that leaf length was drastically reduced, as was stem length below the flowers. While individual flower size was not affected, the length of the inflorescence (flower cluster) was reduced, leading to a tighter appearance. Our trials exploring cultivar effects and alternative application methods continue.

Narcissus

Many pot daffodils cultivars grown are sprayed with 1,000-2,000 ppm Florel (ethephon) when the leaves and/or flower stem are 3-4" long in the greenhouse. With some cultivars, and especially for late crops where plants have received excessive cold weeks, a second spray 2-3 days later is suggested. Data for many cultivars can be found in the Forcer's Guide.

One cultivar that has no height control recommendation in the guide is 'Tête-à-Tête', the most highly used pot daffodil in North America. As mentioned above, this cultivar is susceptible to excessive elongation from the moment the first flowers open. In the postproduction phase, we have seen positive results from Florel sprays (1,000 ppm) applied in the greenhouse, at a stage when leaves are substantially unfolded, but before buds are readily visible. We have also seen positive results with Bonzi applications, either as pre-plant dips (Figure 7). pre-cooling drenches, or as drenches 1-3 days after placement in the greenhouse. All three methods with Bonzi have given positive results over a two-year period. At present, however, we still consider these to be experimental treatments, and look forward to being able to provide more concrete recommendations in the future.

Muscari (grape hyacinth)

The grape hyacinth is a highly desirable plant with wonderfully fragrant flowers. Unfortunately, the leaves grow too long and detract from the plant. This is because Muscari leaf growth begins at the end of summer. If you have grape hyacinths perennialized in your garden, you will see a lush crop of leaves emerge in early fall and persist through the winter.

Typically, growers plant grape hyacinths in the fall, and place into the rooting room for 14-plus weeks, depending on the marketing date. In the rooting room, leaf growth is retarded by low temperature, especially if the cooler is running at or close to 32F. Upon moving to the greenhouse, leaf growth is very rapid, and much more vigorous than flower stem growth. Consequently, flowers are often buried in the foliage. We have not worked on a growth regulator solution to this problem, but do know that "late-planting" is an effective method of producing a high quality plant with shorter leaves.

Late planting is simply planting the bulbs after a substantial part of the cooling phase is complete. Thus, bulbs would be cooled dry (unplanted), using the regular rooting room. Bulbs are planted only after a significant proportion (perhaps 70-75%) of the cold weeks have elapsed. Then, bulbs are planted and cooled at 40-45F for the last 25-30% (3-4 weeks) of cold. It is critical to give the proper *total* length of cold (before and after planting), as the bulb perceives cold in both stages. Delayed planting has no effect on flowering date or quality, but does give shorter, less rank leaves and markedly improves plant quality (Figure 8).

Contact information: wbm8@cornell.edu. Thanks are expressed to the Dutch Exporters Association for Flowerbulbs and Nursery Stock, SePRO, Uniroyal, and Valent USA for financial and material assistance with this research. Also thanks to Cornell's Barbara Stewart, and the three Dutch interns involved with these projects: Dirk Warmerdam, Jeffrey Wagemaker, and Pieter Heemskerk.

About the Flowerbulb Research Program

The 2002 spring season represents the second major forcing year of the Flower Bulb Research Program at Cornell University. Established in 1998, the first two growing seasons were devoted to facilities upgrades (including new greenhouses), installation of about 700 square feet of state-of-the-art cooling facilities (rooting rooms), and capacity building of students and technical support. Cornell's flowerbulb work is conducted in close cooperation with a research advisory group from the Netherlands, with input from many growers and industry stakeholders in the U.S. Major areas of emphasis include the development of new forcing information (for example, the use of Fascination on lilies), evaluation of bulb cultivars for landscape use in differing climactic areas of the US (including upstate New York, Long Island, and the southeastern US in cooperation with Jim Faust at Clemson University), packaging and handling of bulbs, especially for spring retail sales of bulbs such as garden lilies, and the analysis of factors affecting deer and vole predation of bulbs.

Table 1. Selected recipes for the preparation of PGR drench solutions for bulb crops grown in 4" or 6" pots.

Chemical and dose (mg per pot)	ppm of solution	Fluid ounces per gallon of final solution	Milliliters per gallon of final solution	Milliliters per liter of final solution
	For 4" pots, apply 2 fluid ounces (60 ml) per pot			
A-Rest				
0.125	2.1	1.0	30.2	8.0
0.25	4.2	2.1	60.5	16.0
0.50	8.5	4.1	120.9	32.0
1.0	16.9	8.2	241.9	64.0
Bonzi				
0.5	8.5	0.3	8.0	2.1
1.0	16.9	0.5	16.0	4.2
1.5	25.3	0.8	24.0	6.3
2.0	33.8	1.1	32.0	8.4
Sumagic				
0.1	1.7	0.4	12.8	3.4
0.2	3.4	0.9	25.5	6.8
0.3	5.1	1.3	38.3	10.1
0.4	6.8	1.7	51.1	13.5
	For 6" pots, apply 4 fluid ounces (120ml) per pot			
A-Rest				
0.125	1.1	0.5	15.1	4.0
0.25	2.1	1.0	30.2	8.0
0.50	4.2	2.1	60.5	16.0
1.0	8.5	4.1	120.9	32.0
Bonzi				
0.5	4.2	0.1	4.0	1.1
1.0	8.5	0.3	8.0	2.1
1.5	12.7	0.4	12.0	3.2
2.0	16.9	0.5	16.0	4.2
Sumagic				
0.1	0.8	0.2	6.4	1.7
0.2	1.7	0.4	12.8	3.4
0.3	2.5	0.7	19.2	5.1
0.4	3.4	0.8	25.5	6.8

Table 2. Guidelines for preparation of Florel solutions for use as foliar sprays on hyacinths or daffodils.

Parts per million	Fluid ounces per gallon of final solution	Milliliters per gallon of final solution	Milliliters per liter of final solution
500	1.62	47.86	12.64
1,000	3.24	95.73	25.29
2,000	6.48	191.46	50.58

Overview of one of the greenhouses used by Cornell's Flowerbulb Research Program

Figure 1. 'Tete a Tete' narcissus. While a miniature plant for growers, it shows robust growth in the postharvest chain. Left: plant in a 4" pot at the stage of the first flower opening. Right: similar plant 7 days older than plant on the left, after being in an interior room at 70F.

Figure 2. Effect of length of cold on height of tulip cultivar 'Pinocchio'. Plants were given 17 weeks (left panel) or 22 weeks of cold (right panel). Within each panel, the treatments were (left to right): Control, 1 mg Bonzi drench, 2 mg Bonzi drench. (Plants in the right panel had been in a cooler for a day before the photo was taken).

Figure 3. Tulip cultivars 'Crème Upstar' (top), 'Friso' (middle), and 'Gabriella' (bottom), each in 6" pots and cooled for 15 weeks. In each panel, treatments were: Control, 1, or 2 mg Bonzi applied as a drench.

Figure 4. ‘Apeldoorn’ tulips in 4” diameter pots. Bulbs were dipped for 10 minutes in PGRs, planted, cooled for 16 weeks, and forced at 17C. Treatments are L to R: Control (water), 50, 100, 200, 400 ppm Bonzi, 5, 10, 20, 40 ppm Sumagic.

Figure 5. Importance of cultivar selection. Hyacinth 'Blue Jacket' (left) and 'Delft Blue' (right). Both in 4" pots and cooled for 15 weeks.

Figure 6. Prepared 'Anna Marie' hyacinths precooled at 48F starting 5 October. On 1 November, bulbs were dipped for 10 minutes into growth regulator solutions, planted 2 November, and placed back into the cooler (with temperature decreasing from 48 to35F) for a total of 13 weeks of cold. L to R: Control, 400, 200, 100 ppm Bonzi, 40, 20, 10 ppm Sumagic. Plants were forced to the first open flower stage, then placed in a low light room at 70F. Photo taken 7 days later.

Figure 7. 12/14 cm 'Tete-a-Tete' plants, cooled 15 weeks, forced to bud color, then held 7 days in a low-light, 20C postharvest room when the photo was taken. L to R: Control, 50, 100, 200, 400 ppm Bonzi, given as 10 minute pre-plant dips.

Figure 8. Effect of planting date relative to start of cold on growth of grape hyacinth (*Muscari armeniacum*). All plants received a total of 16 weeks of cold at 45F. L to R: planted at the start of cold, or planted after 4, 8, or 12 weeks of dry cold. All plants were moved to the greenhouse on the same date. Note shorter leaves on plants planted after increasing duration of dry cold.