Information

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Growth regulators

Regulating plant growth is becoming a normal part of the plant production on many protected ornamental crops. Stretching due to high temperatures or low light can be a difficulty experienced by many growers. To prevent excessive stem elongation, a number of non-chemical and chemical control options are available. The three primary methods for controlling plant growth are biological, physical, and chemical. For most glasshouse operations, a combination of factors is used to manipulate plant growth. Each is covered below.

Non-chemical Control

Breeding Control

Growing varieties that are shorter growing is often the first step available to growers. While this may work in theory, it may not be commercially practical. Many customers demand specific colour or growth form characteristics, and shorter growing varieties with these attributes may not be available. Therefore, physical or chemical control strategies must also be incorporated into a production plan.

Physical Control

Knowing how the growing environment and cultural practices can affect plant growth will help in managing a crop's growth. There are a number of physical control options available: container size, timing, water stress, nutrient stress, mechanical conditioning, spacing, light quality and quantity, pinching and temperature.

Container Size

Restricting roots can be used to control plant growth. This is done by utilizing a small container or by increasing the number of plants per pot. This method works especially well when other production parameters such as ample light and proper nutrition are provided.

Timing

One of the most effective methods of controlling excessive plant growth is by crop timing. Simply staggering the finishing times of a crop at two to three week intervals are very effective with many crops, such as bedding plants. This ensures that a new supply of plants will always be available, avoiding the need to hold a crop, which can become leggy.

Water stress

A traditional method of controlling plant growth is to withhold water. Water stress can be used on a number of crops, including impatiens and tomatoes. Allow the plants to wilt slightly between waterings, but do not allow them to reach the permanent wilting point. This will lead to shorter plants, but may have the undesirable effect of reduced plant quality, delayed flowering, or premature and weak flowering.

Nutrient stress
Reducing or withholding fertiliser tends to slow overall plant growth. Limiting the amount of nitrogen to 50-100 ppm will help control growth of many crops, such as bedding plants. The type of nitrogen supplied can also impact plant growth. Relying on nitrate nitrogen instead on ammoniacal nitrogen or urea nitrogen forms (which encourage lush growth) will also help.

Phosphorus also promotes plant growth. Plug producers commonly use low-phosphorus fertilisers, such as 13-2-13 cal-mag or 15-0-15, which does not contain phosphorus, to help limit stem elongation.

Mechanical conditioning
Brushing plants has been found to be a very effective way of controlling plant height (30-50%) of many vegetable transplants of herbs. This is especially important for these crops since no chemical control measures are available. Brushing involves the movement of a PVC pipe or wooden dowel rod over the top third of the plant. Researchers at the University of Georgia suggest that the plants should be brushed daily for about forty strokes to obtain the greatest effect. The foliage should be dry to avoid damage to the leaves. This method is not effective on brassicas, such as cabbage or broccoli, and should not be used if foliar diseases are present.

Spacing
Plants are spaced at certain distances to obtain marketable product and reasonable profits per square metre of production area. There is a tradeoff between pot spacing and plant quality. Closer spacing tends to reduce plant quality (strectched, less bushy plants with thinner branches) but results in a greater number of containers per area of production, whereas greater spacing increases plant quality but yields fewer containers per square metre. Optimum spacing would allow the leaves of one container to slightly overlap the leaves of adjacent container.

Light quality and quantity
Higher light quality tends to limit plant elongation, thus resulting in shorter plants. Low light conditions caused by late spacing, crowding, or too many hanging baskets overhead can lead to leggy plants and should be avoided. Photoperiod also can be used to control plant growth. This practice is widely used with pot chrysanthemums by providing taller varieties with only one week of long days (LD) to limit vegetative growth when compared to shorter varieties that receive three weeks of LD to promote growth. Work from HDC shows that stem length is reduced on some plant species by the use of blue films on tunnels.

Temperature
Temperature manipulation can be used very effectively in controlling plant growth. Using temperature regulation on protected crops provides good control over "stretch". Plants subject to cooler days and warmer nights will elongate less. Research shows that dropping the first two hours after sunrise by up to 5°C lower (Negative DIF) is sufficient to regulate the plant even if the daytime temperature continues to rise for the rest of the day. In practice this is achieved by combining ventilation and heating controls, best achieved by computer control.

Chemical Control

To control excessive plant growth, many crops require the use of chemical growth regulators (PGRs). Most of the commercially available PGRs are anti-gibberellins and work by inhibiting gibberellin (GA) synthesis within the plant. Gibberellins promote cellular elongation, so without them, cells do not elongate as much and plants do not grow as tall.

PGR types

There are a number of PGRs available for height control, and they vary in their degree of relative activity. Table 1 lists some of the important attributes of each one. Additional comments are listed below.

B-Nine SG/ Dazide Enhance

Daminozide is probably the most widely used PGR in the United Kingdom. It is actively transported within the plant and only used as a foliar spray. Daminozide has a shorter residual effect, so multiple applications are required. Its efficacy is lower in warm climates. Because it has a lower residual effect, phytotoxicity rarely occurs, but late applications can delay flowering.

Daminozide rarely causes phytotoxicity, but like all PGRs, late application can negatively affect flowering.

Bonzi/ Pirouette

Paclobutrazol is one of the more active PGRs. It is not actively transported within the plant (phloem), so applications to the leaves do not move to other parts of the plant. Paclobutrazol is readily absorbed by the stems or roots and transported by the water flow (xylem) to the growing point. Paclobutrazol is used as either a foliar spray or drench. Typically only a single application is made, although some growers do experiment with multiple applications at lower rates. Late applications or excessive rates can cause stunting or delayed flowering. Pirouette requires a EAMU 2017-1269 for a drench application.

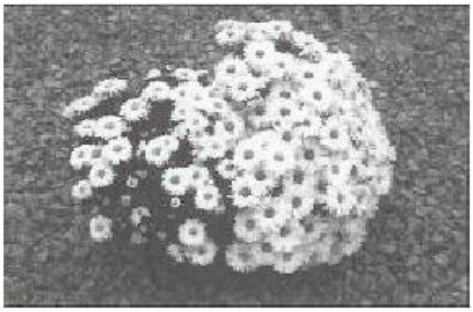
Stabilan 750

Chlormequat also is actively transported within the plant. It can be applied as a foliar spray or drench. Growers primarily use chlormequat on geraniums (*Pelargonium*) and poinsettias (*Euphorbia*). It has a shorter residual effect, so multiple applications are required. Phytotoxicity can occur with rates greater than 1,500 ppm on geraniums or poinsettias. Stabilan 750 requires an EAMU 2018-0371**.**

Yellow spotting of the newly expanding leaves can occur with chlormequat rates greater than 1,500 ppm.

Cerone

Ethephon is not actively transported within the plant but is readily absorbed by the leaves and stems. So uniform coverage is required to obtain optimum results. It is applied as a foliar spray. Cerone prevents flowering and promotes branching of stock and finished plants. Residual effects can last six to eight weeks, so timing of application is important. Cerone requires an EAMU 2012-2366 for use in ornamental plant production.



Complete coverage is required with Cerone to obtain even growth.

Configure

This cytokinin, 6-benzyladenine, is a potent growth regulator for ornamental plant shaping. It promotes cell division and suppresses apical dominance to increases flower number and plant branching. In addition, applications may reduce the overall height of the plant resulting in more compact and marketable plants. Its transport is limited within the plant but is readily absorbed by the leaves and stems. Uniform coverage is required to obtain optimum results. It is applied as a foliar spray.

Configure increases the side shoots on Echnicea giving a fuller plant with more shoots

Regalis Plus

Prohexadione inhibits gibberellin biosynthesis within the plant leading to reduced shoot growth. Foliar applied and absorbed by leaves and stems, it is translocated within the plant. Some phytotoxicity has been reported so caution should be used with dose selection. Regalis Plus requires an EAMU 2019-2153 for use in protected ornamental plant production and 2015-0175 for ourdoor ornamental plant production.

Table 1. Comparing Attributes of Growth Regulators

Factor		B-Nine	Bonzi	Cerone
Chemical		Daminozide	Paclobutrazol	Ethephon
Active ingredient		85%	0.4%	3.9%
Activity level		+	+++	+
Difficulty of use		+	+++	+
Multiple Applications		+++	+	++
Application[1]	Foliar spray	Yes	Yes	Yes
	Drenches	No	Yes	No
	Dips	cuttings	bulbs, cuttings	cuttings
Chemical absorption	Ease of absorption	+	+++	++
	Time (hrs)	18-24	0.5-1.0	12-16
	Factors that improve absorption	High humidity, limited air movement	Normal glasshouse conditions	Avoid hot, sunny conditions
	Translocation in the plant	+++	+	+++
Absorption sites	Leaves	+++	+	+++
	Stems	-	++	-
	Roots (media)	-	+++	-
Typical concentrations	Foliar sprays (ppm or mg/l)	1,250 – 5,000	2-60	250-1,000
	Drench (mg active ingredient/pot)	-	0.1 – 3.0	-
Other factors	Does pine bark affect a drench?	-	++	-
	Phytotoxicity potential	+	+	++ Avoid plant stress
	Overdose potential	+	+++	++
	Influence of water pH	-	-	Best at pH 4
Shelf Life	In the bottle	At least 2	At least 4	Indefinite
	Mixed spray solution	Within 24 hours	Within one week	Within 4 hours

Not applicable = -, Degree of activity: (+) least to (+++) greatest, [1] Check label for UK approved uses.

Efficient Use of PGRs

There are a number of factors that influence the efficacy of PGRs. Each one needs to be considered in order to obtain suitable and consistent results.

Timing

PGRs work by controlling cell elongation before it occurs. They are not plant shrinkers. Therefore, the timing is important to match the application with the desired stage of growth to prevent stretch. Recommendations vary by the type of PGR used. For many crops, the less active PGRs such as B-Nine require the first application be made within a few weeks of potting the plant, generally when there is 1-2" (3-5 cm) of new growth. Growth is controlled in stages by using multiple PGR applications. This allows for the greatest flexibility in deciding when and how much chemical to apply, so factors such as weather conditions and plant vigour can be taken into consideration.

PGRs such as Bonzi have a greater efficacy, and applications are made when the plant has developed sufficient canopy growth. For example, with autumn pansies (*Viola*) the Bonzi label recommends an application when the plant is 2" (5 cm) in diameter. In general, only a single application is made.

Labels for all of the PGRs have recommendations for how late you can make an application in order to avoid a delay in flowering or smaller flowers.

Target

The target tissue for applying a PGR depends on the chemical type and the plant species. Most PGRs are applied as a foliar spray, a very cost-effective and time-efficient way to apply PGRs. Media drenches also work effectively for a number of plants. Drenches are suitable for plants that are not as responsive to foliar sprays, for example, many of the spike-flowered perennials, dahlias, and many of the bulb crops.

Research has also been conducted on dipping. This procedure is most used on rooted cuttings prior to transplanting or with bulbs. For many crops, a specific PGR concentration and dipping time should be followed. Dips are an excellent way to apply PGRs, but disposal of the left-over dip solution is a concern.

Environmental conditions

Environmental conditions can have a significant impact on the efficacy of a PGR. Applying PGRs early in the morning when the evaporation rate is lower will allow for greater chemical uptake. Plants should not be water stressed when PGRs are applied, as the risk of phytotoxicity increased with stress. After application, allow the PGR to dry. During this time, avoid wetting the leaves. Daminozide should be allowed at least four hours before wetting the foliage, while most of the other PGRs only require one hour.

Check plants

How well does the PGR treatment really work? The only way to confirm the efficacy of a PGR is to leave a few representative plants untreated. These "check plants" offer a valuable insight into ways to adjust future PGR applications.

Dosage

The dose to apply to a crop is based on two factors; the solution concentration and the volume of solution applied per area. Foliar sprays and drenches require an even application to obtain consistent results. To accomplish this, base the dose on:

- Measuring out a known amount of chemical.
- Adding it to a known volume of water.
- Applying the growth regulator to a known bench area or applying a known volume of drench to each pot or plant. The volume of drench applied increased with the pot size (specifics are listed on each product label).

PGR mixing tables

When mixing PGRs, take care to accurately measure and apply the chemical. Table 2 provides mixing guidelines for foliar sprays. Drench applications vary by pot size and desired dose, so refer to the product label for exact mixing instructions. As always, the label contains the legal mixing information. Fine Americas (https://www.fine-americas.com/#) has a free downloadable Excel spreadsheet produced by North Carolina State University that enables you to calculate PGR rates (http://e-gro.org/mixmaster/).

Table 2. Mixing Rates for Plant Growth Regulators Used as Foliar Sprays

Chemical	Spray solution ppm (mg/l)	Fl. Oz./gal. of final solution	ml/gal. of final solution	ml/l of final solution
Bonzi	1	0.032	0.95	0.25
	5	0.160	4.73	1.25
	10	0.032	9.46	2.50
	50	0.160	47.32	12.50
	100	3.200	94.64	25.00
	200	6.400	189.28	50.00
Cerone	250	0.81	23.93	6.32
	500	1.62	47.86	12.64
	1,000	3.24	95.73	25.29
	Spray solution ppm (mg/l)	**Dry oz./gal. of final solution**	**g/gal. of final solution**	**g/l of final solution**
B-Nine	1,000	0.16	4.45	1.18
	2,500	0.39	11.13	2.94
	5,000	0.79	22.26	5.88

PGR rates

Recommended rates to apply to most of the commonly grown floricultural crops are listed the PGR rates sheet. These should be used a guidelines, and adjustments should be made for your particular location. Keeping complete records as to how well a PGR application worked will assist you in customising future PGR rates to your own operation. The records should include stage of development, fertilisation programme and weather conditions.

Acknowledgements

Ball Red Book, Beytes C. Ball Publishing. 2003

Tips on Regulating Growth of Crops, OFA Services Inc, 2001