Section D
GROWTH REGULATORS

Recent Changes and New Labels

A section on *Rooting Hormones* has been added to this chapter. See pages D-44 to D-46 & Tables D.17, D.18 & D.19.

Several new labels have been added for use on ornamental crops. However none of these represent new PGR compounds, just alternative sources of existing materials. For example, Piccolo® contains the same active ingredient as Bonzi® and in the identical concentration. Similarly, ProGibb T&O® and Florgib 4L® are identical to GibGro 4LS® which had been previously labeled as a gibberellin source.

Introduction

Using This Chapter

The text in this section provides general use information. Read this section to understand how plant genetics, environmental and cultural conditions, and physical and chemical factors can affect plant response to plant growth regulators.

Look in:

- Table D.1 to find chemical names, REI & EPA registration information.
- Table D.2 to find specific information on PGRs for height control on bedding plants.
- Table D.3 for height control of bedding plant plugs.
- Table D.4 to find information related to PGR usage on other ornamental plants including bulbs, flower & foliage species, and perennials not listed in Tables D.2 & D.3.
- Tables D.5 to D.14 to find dilution rates for specific PGRs.
- Table D.15 to find conversion factors for use in mixing small quantities of PGR.
- Table D.16 for directions on using EthylBloc® to extend plant life.
- Table D.17 to find trade names, EPA registration numbers & REI intervals for rooting agents.
- Table D.18 to find recommendations for pre-formulated dry powder compounds used for plant rooting.
- Table D.19 to find recommendations for using liquid & water-soluble formulations to stimulate rooting.

What are Plant Growth Regulators?

Plant growth regulators (PGRs) are chemical compounds that alter plant growth and development by modifying natural hormonal action. Some PGRs are naturally occurring hormones, others mimic or interfere with the action of natural plant hormones. PGRs can be used to increase or retard plant height, prolong or break dormancy, prolong flower and plant life, abort flowers, or to promote rooting, branching and/or flowering.

PGRs & Crop Management

Optimal crop performance is best achieved with a program of sound cultural practices in a carefully controlled environment. PGRs represent just one part of a complete crop management system. A PGR should be used to induce specific crop responses (e.g., control height or induce branching) that cannot be achieved through normal crop management. Remember, PGRs are not substitutes for proper crop culture and accurate environmental control.

Factors that Affect Plant Response to PGRs

Any factor that affects the rate and quality of plant growth and development can influence the response of a plant to a PGR. All such factors should be considered in a production system. For most PGRs, the recommended dosage to be used for a crop is presented as a range of values. The decision to work at the top or the bottom of the recommended dosage range must be made by each individual grower. To make this decision, growers must consider all of the factors affecting plant response to PGRs relative to the conditions in their own greenhouses, past experiences with these compounds, and the desired effects.

Factors influencing plant responses to PGRs can be separated into three groups: (1) *Plant Factors*, that include (a) species and cultivar, (b) physiological stage of plant development, (c) plant stress, (d) plant size; (2) *Environmental Factors*, that include (a) weather (light and temperature), (b) medium composition, (c) water quality, (d) crop nutrition; (3) *Physical & Chemical Factors***,** that include (a) residual chemical effects, (b) chemical uptake and translocation, (c) spray droplet size, (d) coverage, and (e) application frequency. A brief discussion of each of these factors follows.

Plant Factors

Both *species & cultivars* vary greatly in growth habit, chemical and environmental sensitivity. Chemicals that work on one species may be ineffective on another. Rates that are effective on one cultivar may be too high or too low for another cultivar of the same species. Information on the response of specific crops or cultivars to specific PGRs is not always available. Growers must conduct their own tests to determine the most effective rates.

In general, cultivars with more vigorous growth habits require more PGR than those with less vigorous growth habits. Selecting the proper cultivar is a very important step in limiting the use of PGRs and in achieving satisfactory results. For example, use less vigorous, slow-growing, or naturally compact plants in lieu of chemicals if height control is important or use free branching cultivars if this growth habit is most desirable. Avoid using PGR-sensitive cultivars when possible (cultivars that are easily injured by the chemical being applied) or use the low rate of the recommended range if a sensitive variety is used. Information on plant growth habit is available from plant producers and distributors.

The *physiological stage of development* refers to the actual amount of growth and type of development that has occurred. Bud diameter, lateral shoot length, number of leaves and plant diameter all refer to physiological stages of development. *Two weeks after transplant or pinch* is not a physiological measure of development. In general, the rate of physiological development is more rapid under warm conditions with high light than under cool, darker growing conditions over the same period of time. Chemicals should be applied at the stage of development specified on the label. If the stage of physiological development is not specified, it is important for the grower to keep records to aid in future decision making. Plants treated too early in development or too late in development may not respond properly. Stunting, damage or a total lack of control can result.

Plant stress refers to the physical condition of a plant and is often equated with water stress, i.e., wilted or non-wilted plants. Wilted leaves do not readily absorb chemicals applied as a spray. Applying PGRs to wilting or soon to be wilted plants makes uniform chemical control difficult and may cause injury. Irrigate plants prior to spraying. Only apply PGRs to turgid plants. Stress from disease or extreme environmental conditions will tend to exaggerate the effect of a PGR.

*Plant Size***:** Larger plants require more chemical than smaller plants. To achieve the same level of control, a plant in a 6" pot requires more drench or spray than the same cultivar in a 4" pot produced under similar conditions. Likewise, bedding plant plugs require less PGR than the same species in flats, pots, and baskets.

Environmental Factors

Light and temperature directly affect chemical absorption immediately following a spray and also affect long-term plant response to a PGRs. Weather (light and temperature) conditions that favors the rapid drying of spray droplets on leaves decrease the effectiveness of the water soluble PGRs B-Nine® and Cycocel®, since less chemical is absorbed. Apply these chemicals during cloudy weather, late in the day, or pull shade cloth when spraying to maximize chemical uptake. These chemicals can also be washed off of the plant soon after application. A-Rest®, Bonzi®, and Sumagic® are absorbed within minutes of a spray application and are unaffected by these factors.

Long-term cropping under high temperature/high light conditions favors increased growth rates. Higher dosages of PGR are required and the plants tend to outgrow the PGR sooner. High temperature/low light conditions increase stem elongation or stretch, and produce poor plant quality. Using a growth retardant to try to overcome this problem is an example of attempting to substitute chemical control for good management.

Growing medium composition directly affects the efficacy of drench applications of certain PGRs. The effectiveness of A-Rest® (ancymidol), Bonzi® (paclobutrazol), and Sumagic® (uniconazole) decreases as the pine bark component of a medium increases. In general, the higher the organic matter content of the growing medium the less effective the PGR will be as a drench. As the inorganic content of

the medium increases (for example, the amount of sand, soil, rockwool, or perlite), the effectiveness of drench-applied PGRs increases. Growing medium composition may indirectly influence plant response to PGRs by affecting plant vigor. Plants growing in media that reduce, retard or stunt growth (i.e. cause stress) are especially sensitive to PGRs. A slow growing plant is most sensitive to a PGR application, and will take a longer time to resume normal growth.

Uniform application of a PGR drench is critical for uniform height control when multiple cuttings are growing in a single container such as a basket or pot. If most of the PGR is applied to only one side of the pot, then the plants on that side will be more affected than the plants on the opposite side.

Water quality affects the activity of some PGRs. A combination of high pH (>7) and high alkalinity (>100 ppm calcium carbonate equivalents) may reduce the effectiveness of Florel brand Pistill®.

Crop nutrition (rate of fertilization), along with tightly controlled irrigation practices, has long been used to control crop growth and development. Crops produced with nutritional levels favoring maximum growth require more PGR and less time to outgrow the chemical effects. Conversely, crops hardened (stressed) by limited water and fertility may require little or no chemical control.

Physical & Chemical Factors

Residual chemical effect refers to the length of time a PGR remains active in the plant after application. With chemicals applied as drenches, residual chemical activity in the medium is also of concern. Chemicals such as B-Nine® and Cycocel® lose most of their activity in one to two weeks. A-Rest®, Bonzi®, Fascination® and Sumagic remain active considerably longer (3-4 weeks). The exact length of time a chemical remains active depends on environmental and plant factors previously discussed. Triazol compounds such as Bonzi® and Sumagic® can remain active in the growing medium for months.

Chemical uptake and translocation vary from one PGR to the next. Bonzi® and Sumagic® are actively taken up by plant roots and are readily transported to shoot tips. The same compounds, although rapidly absorbed by leaves, do not readily move out of leaf tissue, and thus, are not effective when applied only to leaves. Spray applications of Sumagic® and Bonzi® must be directed toward plant stems. A-Rest® is actively absorbed and translocated from both plant roots and leaves and is effective as both a drench and a foliar spray. Cycocel® is most effective as a foliar spray but can be used effectively as a drench if high rates are applied. B-Nine® is not effective as a drench and must be used exclusively as a spray.

Fascination® does not disperse well within the leaf, and therefore, thorough spray coverage is essential. However, Fascination® will move into the plant through the roots, resulting in excessive stem stretch. Avoid run-off with spray applications of Fascination®. EthylBloc® is applied as a gas in sealed containers or greenhouses.

Spray droplet size affects the coverage and penetration achieved with a PGR. The smaller the droplet size the greater the coverage (more drops per square inch of leaf surface) and the greater the effect of the chemical applied. However, extremely small drops (fog for example) produce greater drift, take a long time to settle (hours) and may require air circulation to achieve good penetration.

Coverage refers to the volume of solution drenched per quart of potting medium, or sprayed per square foot of bench. Crop coverage is critical. Be consistent. By varying several factors at once (i.e., PGR concentration, plant spacing and volume of delivery or coverage), a grower loses all means of comparison from crop to crop. High carrier volumes (more spray solution applied per unit area) improve penetration and are especially useful with chemicals such as Bonzi® and Sumagic® that require stem contact, and Fascination® that requires total leaf coverage. When using high volume sprays of these PGRs growers are advised to reduce PGR concentration.

Specific spray coverage rates and drench volumes vary among PGR products. Note the following differences:

Pot dia. (in)	A-Rest®	Bonzi®	Cycocel®
	Drench volume (fl oz).		
4"	2	2	3
6"	4	4	6
8"	10	10	8
12"	40	40	—

As a general rule apply 2.5 fluid ounces per quart of potting medium as a drench.

Use the following spray coverage rates unless otherwise noted on the label or in Tables D.2, D.3 & D.4. Note: Bigger plants, by virtue of greater leaf surface areas, receive more total PGR than smaller plants.

- A-Rest®: 2 quarts per 100 square feet
- Atrimmec®: 1 quart per 100-150 square feet
- B-Nine®: 2 quarts per 100 square feet
- Bonzi®: 1-3 quarts per 100 square feet
  For large plants with well-developed canopies use 3 quarts per 100 square feet
- Cycocel®: 2-3 quarts per 100 square feet
- Fascination®: 2 quarts per 100 square feet
- Florel (Pistill)®: No specific coverage listed.
- ProGibb T&O®: 2 quarts per 100 square feet, but rates can vary
- Sumagic®: 2 quarts per 100 square feet
  EXCEPT where noted

Application frequency has a big effect on final plant appearance. In general, repeated or sequential applications at low concentrations produce the best results. Sequential applications at 50-100% of the low rate, or high volume low concentration sprays, are most effective for controlling escapes (e.g. the stray shoots that extend high above the others) on species like chrysanthemum and poinsettia.

Testing

Growers bear the burden to test when specific recommendations are not available. Most of the factors that influence plant response to PGRs interact, making potential effects difficult to predict. Adequate recommendations are not always available and label recommendations sometimes fail to address many of these important considerations. As a result, the burden of testing a cultivar or a crop response to a PGR is with the grower. Individual growers must evaluate the response under their own conditions. Growers need to keep accurate records and test plants on a limited basis in order to gain experience and assess the factors that most influence crop response in their greenhouses. Keep a record of each of the factors previously discussed. Simple techniques, such as recording weekly changes in plant height relative to a ruler or stake permanently placed in a pot, help one to accurately gauge crop response to a PGR application over time.

Alternatives to Plant Growth Regulators

In some cases, cultural control of plant form may be the best alternative available to the grower. In most cases, a combination of cultural manipulation and chemical control represents the best management practices. Cultural alternatives to PGRs include; DIF, light quality, thigmotropism, low phosphorus fertilization & exposure to outdoor growing conditions such as through the use of roll-out benches or similar technologies.

DIF: The day/night temperature difference (DIF) can be used to control stem stretch in many plant species. Night temperatures which are equal to [zero (0) DIF] or higher than day temperatures [negative (-) DIF] reduce stretch. This is especially true when weather conditions favor stretching (i.e., cloud cover and high temperature). When day temperatures exceed night temperatures [positive (+) DIF], stem stretch increases. Growers can manage plant height even under low night/high day temperatures (i.e., 60/70F respectively) by allowing the air temperature to dip to 50-55F for 2-3 hours at dawn. This sunrise temperature dip produces the DIF effect. This is a good alternative to warm night/cool day temperature regimes since plant height is controlled without radically altering the natural daily temperature cycle.

Temperature also affects the rate of plant development. Growth rate is a function of the Average Daily Temperature (ADT). When using DIF, be sure to calculate the ADT associated with the DIF treatment you use. As ADT increases the rate of plant development will increase (reducing crop time on the bench), and conversely, as ADT decreases the rate of plant growth will decrease.

To calculate average temperature, add the night temperature times the length of the night period (in hours) to the day temperature times the length of the day period (in hours), and then divide this total by 24 (the number of hours in the day).

Light quality: End-of-day light quality has an effect on plant development similar to the DIF effect. The ratio of red to far-red light, the photomorphogenic radiation, affects stretching and branching of many plant species. Increasing the end-of-day red light component results in plants with shorter internodes and more breaks. By comparison, increasing the end-of-day far-red light component produces plants with longer internodes and less branching. Researchers are currently studying the use of end-of-day light and developing colored greenhouse films for controlling plant form.

Thigmotropism refers to a plants response to mechanical touch. Vibrating, shaking, or brushing a solid object over a plant will induce this response. Plants regularly treated in this manner remain more compact than plants grown undisturbed.

Low Phosphorus Fertilization: All plants need phosphorus to achieve normal growth and normal flower development. However, with many plant species, low phosphorus fertilization can be used to control plant height without adversely affecting flowering and subsequent garden performance. Fertilizers with low phosphorus content, such as 20-1-20 or 20-2-20, will provide adequate phosphorus for growth and development but restrict stem elongation. As an alternative, no-phosphorus fertilizers such as 15-0-15 or 20-0-20 can be alternately applied with moderate phosphorus fertilizers such as 15-5-15 to achieve the same effect.

This technique is especially valuable on vegetable bedding plant species that cannot be treated with PGRs. For example, tomato height can be controlled with low phosphorus nutrition and the plants will fully recover from the stress once in the field. Growers should beware that species will vary in tolerance to low phosphorus stress and that prolonged or extreme phosphorus deprivation may permanently impair the normal growth and flowering of certain plants.

Exposure to Outdoor Growing Conditions: Plants exposed to outdoor conditions through the use of technologies such as roll-out benches, hi-tech cold frames or similar technologies, do not stretch as much as those produced exclusively in the greenhouse. Temperature, wind and vibration, and high light may all contribute to decreased stretching of crops produced under outdoor conditions.

Formulating and Applying PGRs

Recommended formulations vary with each product. Read the entire label and use the product according to directions. Measure the dosage accurately. Use only properly calibrated weighing and measuring devices. Note: Dosage recommendations for some PGRs are based on the concentration of the applied solution, while recommendations for other PGRs are based on total active ingredient (a.i.) per pot.

Application Methods

PGRs are usually applied either as sprays or drenches. The exceptions include bulb dips & soaks with lilies, cutting dips, pre-plant soil-surface sprays (PSS), gaseous fumigation (as per EthylBloc®) and the use of rooting hormones on woody and herbaceous cuttings. When using a PGR for the first time, treat a small group of plants and keep accurate records of the response and of the prevailing plant status, and environmental and physical conditions in the house.

Many PGR products specify a single mode of application for the grower to use (e.g., B-Nine®, Fascination®, Florel brand Pistill®, and Atrimmec® are used solely as sprays); others give the grower a choice (e.g., A-Rest®, Bonzi®, Cycocel® and Sumagic® can be applied as drenches or sprays). In general, sprays require less labor and are more convenient for growers. The actual amount of active ingredient used with a spray may be more or less than with a drench depending on the PGR (e.g. Cycocel® uses considerably less a.i. with a spray; however, Bonzi® and A-Rest® require less a.i. when applied as drenches). Sprays require great care to achieve uniform coverage. Sequential, low concentration sprays produce the best quality crops. Drenches distribute the active ingredient more evenly within the plant, give better control, and are less likely to damage leaves.

When Applying Sprays

1) Use only on recently irrigated, turgid plants.
2) Observe the proper waiting period between PGR spray application and overhead irrigation - several hours (until dry) for B-Nine® and Cycocel®, while A-Rest®, Bonzi®, and Sumagic® are absorbed within minutes.
3) DO NOT use wetting agents with any of the plant growth regulators listed in Tables D.2, D.3 & D.4. Avoid the use of uptake enhancers. Spray adjuvants increase the risk of plant injury.
4) Only use properly functioning spray equipment and only use sprayers dedicated exclusively to PGR applications.
5) Avoid chemical waste. Place plants close together and cover the bench at recommended rates.
6) Sequential applications of A-Rest®, Bonzi® and Sumagic® at the lowest rate produce the best crop uniformity.

When Applying Drenches

1) Only treat plants with well-developed root systems.
2) Use only on recently irrigated pots containing a uniformly moist medium.
3) Apply recommended drench volumes in each pot (enough to uniformly wet the entire root system). Roughly 2.5 fl oz per qt of potting medium.
4) Avoid waste from excess dripping.
5) Make sure drench treatments are applied uniformly to the potting medium when multiple plants are in a single container such as a hanging basket.

Directions for Mixing

1) Mix and use PGR solutions the same day. Do not store (not even overnight).
2) Remember the final volume of a mix solution includes both water and PGR (i.e., a 16-ounce per gallon solution contains 16 ounces of PGR and enough water to equal one gallon of solution). See Table D.15 for help in formulating small quantities or low rates.
3) Do not add a spreader-sticker (see 'When applying sprays').
4) Do not mix PGRs with pesticides or fertilizers.
5) Always read and follow label directions.

Storage

Store PGRs in tightly sealed containers placed in a cool, dry, dark location. Temperatures above 100-120F and below freezing adversely affect the storage life of most PGR products. The storage life of Cycocel® and B-Nine® meet or exceed two years under proper storage conditions. A-Rest® lasts at least three years and Atrimmec® and Florel brand Pistill® last indefinitely when stored properly.

State Registrations

The law requires all pesticide products to be registered in the state where they are to be used.

Products registrations change from year to year. The information herein is accurate as of publication but is subject to change. For questions regarding product registration use EPA Registration Numbers (see Table D.1) and contact the pesticide division in your state (see Appendix). See Table D.17 for EPA registration information for rooting compounds.

Table D.1. Common chemical names, EPA registration numbers, and re-entry intervals (REIs) for growth regulators registered for use on greenhouse ornamentals**.** (See Table D.17 for information on Rooting Agents.

Trade Name	Common Chemical Name	EPA Registration Number	REI* (hrs)
A-Rest®	ancymidol	67690-2	12
Atrimmec®	dikegulac sodium	2217-776	12
B-Nine®	daminozide	400-478	24
Bonzi®	paclobutrazol	100-996	12
Cycocel®	chlormequat	241-74 59807	12
EthylBloc®	1-methyl-cycloprepene	71297-1	Vent
Fascination®	N-(phenyl methyl) -1H-Purine 6-Amine & Gibberellins A_4 A_7	73049-41	4
Florel brand Pistill®	ethephon	264-263	48
Florgib 4L®	gibberellic acid (GA_3)	62097-10	4
GibGro® 4SL**	gibberellic acid (GA_3)	55146-62	4
Piccolo®	paclobutrazol	62097-11	12
ProGibb® T&O	gibberellic acid (GA_3)	73049-15	12
Sumagic®	uniconazole-p	59639-37	12

*ReEntry Interval. See labels for specific instructions.

** GibGro is also available in (5, 10, & 20% powder) each with a separate EPA registration number.

Notes: