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Flurprimidol: A growth retardant

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Abstract
Controlling plant size is one of the most important aspects of crop production. Growers can control crop height genetically, environmentally, culturally or chemically. Genetic control of plant height is primarily achieved by selecting shorter cultivars. Environmental control involves manipulating light (increasing light intensity, minimizing far-red light, and photoperiod) or temperature (reducing the difference between the day and night temperatures, or DIF). Cultural control includes moisture management (stress) and phosphorus or nitrogen deprivation. These techniques can be effective height-suppressing strategies for some crops, but these techniques may not work equally well for each crop under a common environment. An alternative, effective strategy for controlling plant height is to use chemical plant growth retardants (PGRs). Flurprimidol is an alternative for Ancymidol that is at least two times as active and more stable. It is a synthetic inhibitor of Gibberrelic Acid biosynthesis. It is a growth retardant commonly use in horticultural crops in Europe. Flurprimidol is a pyrimidinyl carbinol type plant growth retardant. It acts by reducing the biosynthesis of gibberellins and translocation in plants is apoplastic. Flurprimidol is used on container grown ornamentals, pot plants and bedding plants to reduce internode length.

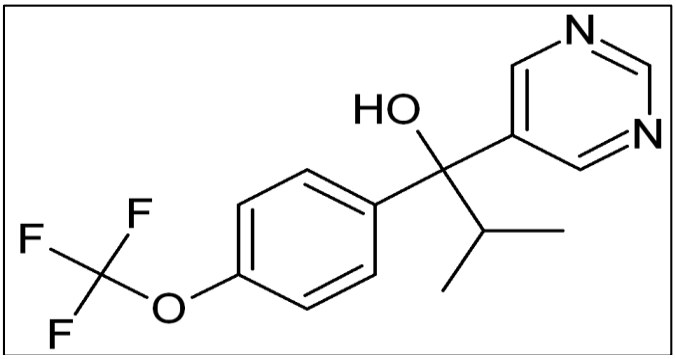
Keywords: Growth retardant, physio-chemical properties, mode of action, functions in plant

Introduction
Flurprimidol, is a nitrogen-containing heterocycle compound of the pyrimidine chemical class. Flurprimidol acts as an inhibitor of enzymes catalyzing the steps in the GA biosynthetic pathway that involve oxidation of ent-kaurene to ent-kaurenoic acid, a GA precursor.
IUPAC name - 2-methyl-1-pyrimidin-5-ly-1-{4-(trifluoromethoxy) phenyl}propan-1-ol
Tread Name - 1) Cutless – for nursary and landscape 2) Toflor – for green house, tissue culture, in-vivo.
Flurprimidol is the most recent plant growth regulator to be introduced to grower of containerized ornamental plants in commercial nurseries, greenhouse, and shade houses within the U. S. However, while it may be the newest PGR tool domestically, it has been successfully used by European growers for many years to produce some of the world's finest and most outstanding ornamental crops.
The positive attributes of flurprimidol will allow growers to produce top quality plants resulting in improved marketability of their crop. Today's consumer demands the highest quality plants that are compact, full of vibrant blooms, possess dark green foliage, and will demonstrate outstanding performance. Growers now have a PGR tool that provides the ability to grow that consumer demand. Some of the many benefits of using Flurprimidol include:

- Flurprimidol is active on a wide range of crops, which makes selecting a PGR less complicated.
- Flurprimidol's unique activity range allows growers to control even the most vigorous plant species while provinding the proper amount of control for slower growing crops.
- Flurprimidol has improved plant uptake vs. other PGR's, which in many cases results in lower application rates required to achieve optimum growth regulation.
- Flurprimidol is highly activity through plant rooots, which lends itself to uniform growth regulation and reduced flower delay.
- European growers have experienced that plants treated with flurprimidol produce darker blooms and fewer faded blooms.
- Flurprimidol also strengthens and tones plants, which reduces shipping losses. Dark green foliage is evident in flurprimidol treated plants.

Chemical and Physical Properties

Appearance	Crystal, Powder
Colour	Off-White
Odour	Slight Aromatic
pH Value	6.5 - 8.9 50%
Melting Point [^{0}C]	94 – 96
Vapour Pressure	3.64 × 107 mm Hg
Relative Density	0.87
Solubility	120 – 140 mg/l
Chemical Names	Flurprimidol [ANSI:BSI:ISO]; CHEBI:81765
Molecular formula	C15H15F3N2O2
Molecular Weight	312.28701 g/mol



General Structure of Flurprimidol

History

- Flurprimidol (SePRO, Carmel, Ind.) was a molecule discovered over 20 years ago by Eli Lily and Company.
- It is a "Type 2"PGR, similar in its mode of action to A-Rest, Bonzi, and Sumagic.
- Flurprimidol has been labeled as Cutless for turf use in the U.S. and commerciall introduced as Topflor in Europe for greenhouse crops.
- Cutless has been trailed extensively on nursery crops such as butterfly-bush (Keever and Gilliam, 1994) [6], Holly (Keever *et al*., 1994) [6], and Mexican sage (Burnett *et al*., 2000) [1].
- Commercial recommendations for applying Topflor foliar sprays to a number of greenhouse crops have been developed for European growers.

How to Work Flurprimidol

Flurprimidol [alpha-(1-methylethyl)-alpha-(4-(trifluorometho xyphenyl)-5 pyrimidine -menthanol] which is a Class B PGR that restricts cell elongation by inhibition of active GAs, specifically production of the GA_1 hormone (Sun and Kamiya 1994) [9]. Gibberellins are naturally occurring phytohormones directly related to vegetative growth and flower development (Hooley 1994) [5]. Flurprimidol inhibits gibberellins production early in the isoprenoid pathway by binding to proheme iron of cytochrome P450 and inactivating the monooxygenase enzymes responsible for the conversion of ent-kaurene to GA12-aldehyde (Grossman 1992) [3].

Although, the production of GA differs in many plant species and even among plants of the same species, several growth regulators perform by inhibiting this pathway without adversely affecting internal plant functions (Rademacher 2000) [7].

It is suggested that flurprimidol may produce broader physiological effects than inhibition of GA synthesis. Graham *et al*. (1994) [2] observed flurprimidol treatments not only blocked GA1 but also caused a significant decrease in abscisic acid (ABA), another major plant hormone. ABA is responsible for signaling plant response due to environmental stresses and may cause plants to reallocate GA (Hansen and Grossman 2000) [4]. Gibberellins inhibitors can cause heavier bud, flower, and seed sets along with pigment intensification (Redding *et al*. 1994) [8].

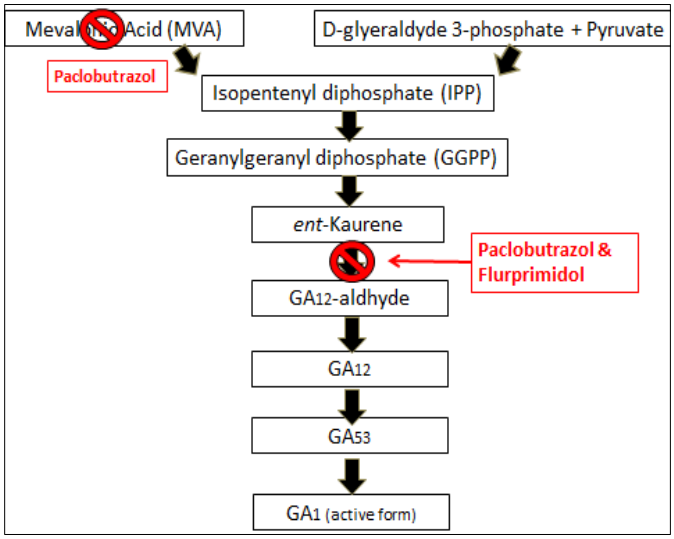


Fig 1: Isoprenoid pathway for the production of Gibberellic acid. A simplified schematic of the steps involved in GA biosynthesis and site of action for specific PGRs (Radmacher 2000).

Factors that influence Topflur efficacy

Cultivars or varieties within a given plant species may respond differently to Topflor. Varieties that are taller or more vigorous generally require more Topflor than naturally short or less vigorous varieties. Stage of plant growth at the time of application will also influence the amount of Topflor needed.

Environmental conditions can also strongly influence the response to Topflor and, therefore, the amount of product applied. Growers in warm climates may need to use higher rates and/or more applications compared to those in cooler climates. The Topflor rate, as well as number of applications, may also vary depending on the time of year, with higher rates and/or more applications needed during warmer months.

Cultural practices may affect the plant's response to Topflor. Plants that are grown at close spacing or in small pots and using high water and fertility levels may require higher rates of Topflor to achieve the desired response. The effectiveness of a Topflor drench may be reduced in root media that utilizes a high amount of pine bark. Another factor that influences the amount of Topflor required for an optimum growth response is application method (spray or drench) and technique including the uniformity of coverage and degree to which the spray solution is allowed to run off the pot.

Functions of Flurprimidol in Plants

- Flurprimidol has been shown to increase the quality of plants, even in the absences of growth reduction.
- Enhanced leaf and bloom color
- Increase chlorophyll content
- Greater leaf thickness
- Stronger stems
- Decrease water loss
- Reduce height
- Delayed anthesis
- Influence flower size, number of flowers, flower longevity.

Flurprimidol Application Method

Plants absorb Topflor through foliage, stems, and roots. Topflor may be applied as a spray, drench or chemigation to achieve the desired plant height control. Use industry standard application equipment, which may include backpack sprayers, low-pressure hand wand drench applicators, or other similar equipment. Additionally, standard chemigation equipment and practices may also be used. Multiple or split applications may allow greater treatment flexibility, more uniform growth regulation, and safety from over-application and may be, therefore, desirable.

Spray

Topflor applied as a foliar spray is absorbed through plant foliage and stems. Additional growth regulation will result from root uptake of Topflor reaching the root medium as runoff from foliar treatments or over-spray.

Drench

Topflor applied as a drench provides treatment accuracy for consistently uniform results. Topflor is readily absorbed by the roots and translocated to the terminals. Root medium should be moist, but not wet at the time of treatment. Best results are obtained when moisture content allows the drench treatment to become well distributed and retained entirely within the pot. This may be achieved by watering the plants the day before treating. Response may be variable if part of the drench solution is lost to flow-through or if root medium is too dry to allow for even distribution of the treatment, especially when multiple cuttings are in the same container.

Application Rates

The amount of Topflor required for an optimum growth response depends upon several factors: desired height, duration of growth response and degree of control, pot size, stage of growth, method of application, season and cultivar response. Species-specific cultural practices such as watering, potting media, fertilization, temperature and light conditions also affect the growth response to a given dosage. Therefore, growers should establish specific application rates based on small-scale treatments under actual use conditions and keep records as to plant species and cultivar sensitivity before Topflor is applied to a large number of plants. The rates recommended on this label are rate ranges and should be used only as a guideline. For spray, drench and chemigation applications, do not exceed the maximum recommended rate 0.36 lbs ai/A for single applications. Do not exceed more than 3.0 lbs ai/A/year. Rate (lbs ai/A) will determine the maximum number of seasonal applications allowed not to exceed 3.0 lbs ai/A/year. If required, repeat applications to the same crop may be applied at 5 to 21 day intervals

Topflor is effective in controlling the height of most ornamental crops. The use and rate recommendations for the species that follow should be a starting point in determining the best rate for your specific cultural and environmental growing conditions.

Conclusion

Flurprimidol clearly plays a significant role in plant metabolism, physiology, flowering, flower development and hence, in plant productivity. Properly and timely application of flurprimidol as foliar spray and drench on both field and horticultural crops will surely improve the plant's morphological, biochemical and yield parameters.

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