

# Plant growth regulators: What and why

Additional research will most likely confirm the promise that PGRs have shown and firmly establish their place in turfgrass management.

Plant growth regulators have been available in turfgrass management for several decades. In recent years, PGR use has increased on golf courses as superintendents have begun to use them to enhance overall turf quality, promote a smooth and uniform playing surface and improve stress tolerance in higher-maintenance areas. The use of PGRs has, therefore, become almost standard practice for turf management on golf courses. This article discusses the various types of PGRs available, their functions, modes of action and intended uses.

## Classification of PGRs

Any substance that influences plant growth and development can be broadly defined as a PGR. Therefore, PGRs generally include any compound that promotes or inhibits plant growth and development. These compounds may be synthetic chemicals or the natural products of plant cells. PGRs produced inside plant cells in small quantities are often referred to as *phytohormones* or *plant hormones*. As used in turfgrass management, the term *plant growth regulator* typically refers to compounds that inhibit or decrease plant growth. In fact, a more appropriate term would be *plant growth inhibitors* or *plant growth retardants*. In recent years, some organic compounds or hormone-containing compounds derived from natural products have received increasing attention in turfgrass management. These products, like growth-promoting hormones, can stimulate plant growth and development without causing known harm to the envi-

ronment. These compounds are classified as plant growth promoters or growth-promoting PGRs, and are collectively called *biostimulants*.

## Plant hormones

The five major classes of naturally occurring plant hormones are: cytokinins, auxins, gibberellins, abscisic acid and ethylene. These plant hormones generally regulate plant growth and development by affecting cell division, elongation and differentiation. They also mediate various physiological responses to help plants adapt to environmental stresses. Each class of hormones has a multiplicity of effects, but has unique physiological functions.

Cytokinins, auxins and gibberellins are typically considered growth promoters, although they can have a negative impact when present in large concentrations. Abscisic acid and ethylene are generally considered growth inhibitors because of their effects on growth inhibition or senescence, but they also have some positive effects on plant growth, especially when plants are subjected to environmental stresses.

## Growth-promoting PGRs: Biostimulants

Biostimulants are complex mixtures of ingredients that may include organic acids, mineral nutrients, hormones or microorganisms. Numerous biostimulant products have been developed in recent years, and many of them are claimed to improve turf quality, rooting and stress tolerance (2).



PGRs are often used to improve the quality of creeping bentgrass putting greens. Photo courtesy of P. McCullough

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**Primo** is a Type II PGR used for growth reduction. The creeping bentgrass plants on the left are shown four weeks after being treated with Primo. Primo was not applied to the plants on the right.  
Photo by Steve McCann

The two most popular ingredients of biostimulants in turfgrass management are seaweed extracts (from kelp or seaweeds) and humic substances (natural organic compounds resulting from the decomposition of organic matter of animals or plants). The use of these types of products on golf courses has been reviewed previously in *GCM* and in scientific publications (1,2,3,7,9,10).

Seaweed extracts, which have been used in turfgrass management for multiple purposes, enable turfgrass to reach its maximum growth potential, but are most beneficial when turfgrasses are subjected to environmental stresses. Therefore, they are best used as a preconditioning treatment for plants before stress-related problems arise, with multiple applications during periods of stress.

Humic acids can be used as soil amendments or foliar sprays. As a soil amendment, humic acid may enhance moisture retention and nutrient availability of the soil, particularly phosphorus and potassium.

Therefore, especially in sand-based putting greens, the best time to incorporate humates into turf would be during grow-in or aeration in order to increase nutrient uptake and rooting.

Microbial inoculants, often known as biofertilizers, have also been used as “biostimulants.” Biofertilizers typically contain spores of beneficial fungi, bacteria or both and also may include some organic compounds such as polysaccharides and amino acids. Bacteria from the genera *Bacillus*, *Pseudomonas* and *Azospirillum* are well known for stimulating growth (6).

### Growth-inhibiting PGRs: Functions and uses

Growth-inhibiting PGRs were initially developed to reduce mowing frequency and suppress seedheads, but their uses are expanding to other purposes such as overseeding, mixing with fungicide to enhance activity, and pre-stress conditioning (8). Most PGRs are synthesized chemicals and some are derived from herbicides. PGRs commonly used as growth inhibitors are classified into three distinct groups based on the mode of action or how they inhibit growth and development of turfgrass plants (Table 1).

#### Cell-division inhibitors: Type I PGRs

One group of growth-inhibiting PGRs, Type I PGRs or cell-division inhibitors, suppress plant growth by inhibiting cell division and differentiation in meristematic regions. They also inhibit shoot extension and suppress seedhead development. Type I PGRs include Embark (mefluidide), Limit (amidochlor) and Royal Slo-Gro (maleic hydrazide). Cell-division inhibitors are absorbed

## Growth-inhibiting PGRs

Active ingredient (trade name)	Turfgrass species							Intended uses		
	Bermudagrass	Creeping bentgrass	Kentucky bluegrass	Perennial ryegrass	<i>Poa annua</i>	Tall fescue	Zoysiagrass	Overseeding aid	Golf green	Seedhead suppression
<b>Type I PGRs: Cell-division inhibitors</b>										
Limit (amidochlor)			yes	yes		yes				yes
Royal Slo-Gro (maleic hydrazide)	yes		yes	yes		yes		yes		yes
Embark (mefluidide)	yes		yes	yes	yes	yes	yes	yes		yes
<b>Type II PGRs: Gibberellic acid inhibitors</b>										
Cutless (flurprimidol)	yes	yes	yes	yes			yes		yes	
Trimmit/TGR (paclobutrazol)	yes	yes	yes	yes	yes	yes		yes	yes	yes
Primo (trinexapac-ethyl)	yes	yes	yes	yes	yes	yes	yes	yes	yes	
<b>Other PGRs</b>										
Proxy (ethephon)		yes	yes	yes		yes				

Modified from (5) and B. McCarty and T. Whitwell, “Plant growth regulators for fine turf” (<http://virtual.clemson.edu/groups/turformamental>).

**Table 1.** Growth-inhibiting PGRs commonly used on golf turf.

through foliage when applied to turf. They can suppress turfgrass growth within a few days of application (five to seven days), but the growth-inhibition effects usually only last a short time.

These PGRs are highly effective in suppressing seedhead formation and are used primarily to reduce *Poa annua* seedheads. The timing of application is critical for effective seedhead control. PGRs must be applied before seedhead formation for good control, and multiple applications may be necessary.

#### *Gibberellin inhibitors: Type II PGRs*

Type II PGRs suppress vertical shoot growth by inhibiting biosynthesis of gibberellin, which is needed for cell elongation. Three common PGRs that are gibberellin inhibitors are Primo (trinexapac-ethyl), Trimmit or TGR (paclobutrazol) and Cutless (flurprimidol).

Primo, which is foliarly absorbed, is likely the most widely used PGR in turfgrass management. It inhibits gibberellin synthesis in the later stages of the biosynthesis pathway. Primo is used on greens and fairways for growth reduction and to improve turf quality, density, chlorophyll content and stress tolerance (8).

Trimmit, TGR and Cutless, which are absorbed through the roots, affect gibberellin synthesis in the early stages and may cause higher phytotoxicity than Primo. Trimmit and TGR are primarily used for growth reduction in cool-season grasses and have recently been applied to suppress *Poa annua* seedheads in creeping bentgrass greens and fairways (4,8).

Turfgrass plants respond more slowly to gibberellin inhibitors than to cell-division inhibitors. Depending on plant species and PGR doses, the effects may be observed within seven to 14 days of application and may last for four to eight weeks. Type II PGRs are used in various plant species and are widely used in both warm- and cool-season turfgrasses.

#### *Other growth-inhibiting PGRs*

Other commonly used growth-inhibiting PGRs include Proxy (ethephon). Proxy promotes ethylene production from leaves, which inhibits cell elongation but promotes leaf senescence. Proxy is primarily used in growth reduction on cool-season turfgrass, but may also reduce seedheads of *P. annua*. Proxy may result in growth inhibition within two weeks of application and last for seven to 12 weeks. However, higher doses may cause leaf senescence.

Some herbicides are also used as PGRs to suppress plant growth or seedhead formation in turfgrass management. Some herbicides such as Roundup Pro (glyphosates), Oust (sulfometuron),

Telar (chlorsulfuron), Escort (metsulfuron), Plateau (imazameth), and Event (imazethapyr + imazapyr) inhibit growth by interrupting the synthesis of amino acids (constituents of proteins for metabolism). Others such as Vantage (sethoxydim) inhibit growth by blocking fatty-acid synthesis. Herbicides are primarily foliage-absorbed. These products are highly toxic and, if they are improperly applied, can easily damage plants.

#### *Caution in the use of growth-inhibiting PGRs*

Irrigation is required following the application of root-absorbed PGRs to increase absorption efficiency by the plants. For PGRs like Primo that are absorbed through foliage, uniform and complete coverage of the turf canopy is required, and the chemical must be fully absorbed by leaves before irrigation or rainfall occurs to achieve the best efficacy. PGRs are most effective in suppressing growth of actively growing turf and should be applied in spring and fall on cool-season turfgrasses and after spring green-up and during the summer on warm-season turfgrasses.

When used improperly, growth-inhibiting PGRs may have negative effects on turfgrass such as: phytotoxicity (burning) of leaves; reduced ability to recuperate from physical injury; and reduced ability to compete with weeds because of inhibited growth. Type II PGRs have a low likelihood of causing phytotoxicity and may be used on putting greens and fairways. The effects of Type I PGRs are relatively less consistent than those of Type II PGRs and can cause turf injury when misused. Type I PGRs are used predominantly in low-maintenance turf areas. Because of their high phytotoxicity, herbicides are primarily used in low-maintenance turfgrass areas for weed control and reducing mowing frequency.

Effects of Primo and Proxy on seedhead suppression of annual bluegrass.  
Photo by John Inguagiato



### Concluding remarks

Numerous PGRs have been developed for turfgrass use in recent years, and both growth-inhibiting and growth-promoting PGRs are gaining in popularity in turfgrass management. Many of the benefits claimed by manufacturers are attractive, and some have been confirmed in independent research. However, research information on these products in general is limited.

Biostimulants provide a promising management tool in promoting healthy and stress-tolerant turf, but their effectiveness is relatively inconsistent, depending on many plant and environmental factors and how products are applied. In general, on-site testing and referring to research reports are the best ways to determine which biostimulants are best for a particular site.

Growth-inhibiting PGRs are widely accepted for controlling growth in various warm-season and cool-season species and for seedhead suppression (primarily for *Poa annua*). Most products provide consistent and satisfactory results when applied according to the manufacturer's recommendations. In recent years, growth-inhibiting PGRs have been used to manage stressed turf, especially under drought and shaded conditions. However, growth-inhibiting PGRs should be used cautiously on high-quality turf because of the potential for phytotoxicity.

Ultimately, PGRs have great potential in turfgrass management, but more research is needed to justify the claims and promises.

### The research says

→ PGRs generally include any compound, synthetic or natural, that promotes or inhibits plant growth and development.

→ Biostimulants are growth-promoting PGRs, most commonly containing seaweed extracts or humic substances. Many of them are claimed to improve turf quality, rooting and stress tolerance, but further research is needed.

→ Type I PGRs, cell-division inhibitors, are highly effective in suppressing seedhead formation and inhibiting growth.

→ Type II PGRs, gibberellin inhibitors, are used primarily for growth reduction. Primo has also been used to improve turf quality, density, chlorophyll content and stress tolerance, and Trimmit and TGR have been used to suppress *Poa annua* seedheads.

→ Because of their high phytotoxicity, herbicides are primarily used in low-maintenance turfgrass areas for weed control and reducing mowing frequency.

### Literature cited

1. Goatley, J.M., Jr., and R.E. Schmidt. 1990. Anti-senescence activity of chemicals applied to Kentucky bluegrass. *Journal of the American Society of Horticultural Science* 115(4):654-656.
2. Karnok, K.J. 2000. Promises, promises: Can biostimulants deliver? *Golf Course Management* 68(8):67-71.
3. Liu, C., and R. Cooper. 2000. Humic substances influence creeping bentgrass growth. *Golf Course Management* 68(10):49-53.
4. McCullough, P., S. Hart and D. Lycan. 2005. PGR programs for annual bluegrass suppression. *Golf Course Management* 73(10):78-81.
5. Murphy, T.R., T. Whitewell, L.B. McCarty and F. H. Yelverton. 2001. Turfgrass plant growth regulators. p. 552-561. In: L.B. McCarty, ed., *Best golf course management practices*. Prentice-Hall, Upper Saddle River, N.J.
6. Nelson, E.B. 1997. Microbiology of turfgrass soils. *Grounds Maintenance* (March) 32(3): 33, 36, 40, 42.
7. Schmidt, R.E., E.H. Ervin and X. Zhang. 2003. Questions and answers about biostimulants. *Golf Course Management* 71(6):91-94.
8. Shepard, D. 2002. Users drive research into new growth regulator applications. *Turfgrass Trends*. 11(4): p. T10-T12, T14.
9. Zhang, X., and E.H. Ervin. 2004. Cytokinin-containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinins and drought resistance. *Crop Science* 44(5):1737-1745.
10. Zhang, X., and R.E. Schmidt. 2000. Hormone-containing products' impact on antioxidant status of tall fescue and creeping bentgrass subjected to drought. *Crop Science* 40(5):1344-1349.

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