PGRs: Metabolism and plant responses

Understanding how PGRs work can help superintendents use these products to benefit the turf and the golf course.

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Turf growth regulators have become a very common management tool for superintendents, many of whom routinely apply plant growth regulators from early spring until early fall of each growing season. Although PGRs are widely used, our understanding of their effects on turfgrass growth and physiology is limited. Several papers in the scientific literature describe the effects of PGRs on clipping production, turf color and ball roll, but there is not nearly as much information on the effects of PGRs on physiological parameters like photosynthesis (4,6), tiller initiation (2,3), respiration (5) and so on.

As the use of PGRs becomes more commonplace, it is important for superintendents to have a clear understanding of the physiological pluses and minuses of their use. Are there downsides to PGR use? Absolutely, but these problems are often outweighed by the benefits. The purpose of this research was to determine several physiological effects of PGRs on turfgrass growth. In particular, we measured the effects of PGRs on photosynthesis, leaf area and tiller number; and we measured the rate of PGR metabolism in several turf species at varying temperatures.

Materials and methods

Studies were conducted at the Landscape Horticulture Research Center on the University of Illinois–Urbana campus and in controlled environment growth chambers. All experiments were repeated over two years. Field-grown Kentucky bluegrass was mowed weekly at 1.25 inches (3.2 centimeters), and clippings were collected.

To measure PGR metabolism, Kentucky bluegrass (*Poa pratensis*) and creeping bentgrass (*Agrostis stolonifera*) were treated with either Trimmit 2SC (paclobutrazol) or Primo Maxx (trinexapac-ethyl) at 4 ounces active ingredient/acre (0.28 kilogram/hectare). Leaf tissue was collected at two, five, eight, 11 and 14 days after treatment for Primo Maxx and two, eight, 16 and 23 days after treatment for Trimmit 2SC. PGR residues were determined by shaking the clippings with a mixture of methanol and water, followed by various clean-up steps, and then using high-performance liquid chromatography to determine the amount of PGR remaining (1).

Photosynthesis

Photosynthesis was measured using a 0.64-square-inch (4.16-square-centimeter) polyethylene cylinder that was placed over the turf. The difference between the concentration of carbon dioxide in air entering the chamber and in air exiting the chamber was used to determine photosynthetic rates.

Leaf area indices

Turfgrass leaf area was measured by removing all the foliage from the 0.64-square-inch (4.16-square-centimeter) circle used in the photosynthesis measurement. Leaves were separated and placed on a flat-bed scanner, and the image was collected and processed using image analysis software.

Results and discussion

PGR metabolism

PGR metabolism studies were conducted under both field and controlled-environment growth chamber conditions. Controlled-environment studies were done in order to understand more fully the role of temperature in PGR metabolism. The results of both field and controlled-environment growth chamber studies show that both Primo Maxx and Trimmit 2SC are degraded more rapidly at higher temperatures (Table 1). The shorter the half-life (the time, measured in days, for the concentration of the PGR in the plant to be reduced by half), the faster the rate of degradation.

Although this finding seems straightforward, two competing processes are both affected by temperature. First, metabolism within the plant would be expected to increase with increasing temperatures; however, uptake of the applied PGR by the plant would also increase with increasing temperature. Which process was more important? Our data clearly show that metabolism trumps uptake. Our field studies showed that, although uptake of both PGRs increased in summer, the increased rate of metabolism at higher temperatures results in less PGR activity under hotter conditions.

Half-lives of Primo and Trimmit

	Growth chambers		Field	
Treatment & species	64.4 F (18 C)	86 F (30 C)	Spring	Summer
Primo Maxx	Half-life (days)			
Kentucky bluegrass	5.3	3.4	5.8	4.2
Creeping bentgrass	6.4	3.1		
Trimmit 2SC				
Kentucky bluegrass	11-15	7-9	15.4	11.5
Creeping bentgrass	9-11	6-8		

Table 1. Half-lives (in days) of Primo Maxx and Trimmit 2SC under growth chamber and field conditions. The shorter the half-life, the faster the rate of degradation.

Primo vs. Kentucky bluegrass

		Tiller number		
Weeks after treatment	Plant height as % of control	Primo Maxx	Control	Statistical significance
1	46	3.0	3.0	NS
2	41	4.8	8.8	*
3	57	8.3	6.3	NS
4	119	12.3	10.3	*
5	129	17.0	10.3	*
6	137	15.5	11.3	*
7	94	19.8	15.0	*

*The Primo Maxx treatment is significantly different from the control. NS, not significant.

Table 2. Effects of Primo Maxx on Kentucky bluegrass plant height and tillering.

This is a particular problem for Primo Maxx because its half-life is relatively short, even under cool conditions. However, under hotter conditions, Primo Maxx disappears rapidly, with a half-life of approximately three days.

This information goes a long way toward explaining why PGRs are less effective in summer. In fact, this research was initiated because superintendents often ask, "Why do the PGRs I use seem to quit working in summer?"

Annual bluegrass control

Another aspect of this research should be interesting to superintendents. Note that in the growth chambers, we compared the metabolism of both PGRs in two turf species, Kentucky bluegrass and creeping bentgrass. Unfortunately, we did not include other turfgrass species such as annual bluegrass (*Poa annua*).

Nevertheless, note that the metabolism of Primo Maxx is very similar for both Kentucky bluegrass and creeping bentgrass. However, the metabolism of Trimmit 2SC is slower in Kentucky bluegrass than in creeping bentgrass. Primo Maxx regulates most species to approximately the same degree. Trimmit 2SC, however, regulates Kentucky bluegrass (and, we guess, a closely related species, annual bluegrass) for a longer period of time than it regulates creeping bentgrass.

This differential growth regulation is what makes Trimmit 2SC an effective product for reducing the proportion of annual bluegrass in creeping bentgrass fairways and greens. When Trimmit 2SC is used regularly over an entire growing season, annual bluegrass is regulated much more than creeping bentgrass (see article in February *GCM*), with the result that the population of annual bluegrass tends to shrink while creeping bentgrass increases. The half-life of Trimmit 2SC is quite possibly even longer in annual bluegrass than in Kentucky bluegrass.

PGR effects on tiller production

PGRs not only reduce the growth of turfgrasses, but they also alter the way turfgrass plants grow. This alteration in growth is best illustrated by the effects of PGRs on tiller production. When a gibberellin-inhibiting PGR — the three that are currently labeled for use in turf are Primo Maxx, Cutless (flurprimidol) and Trimmit 2SC — is applied to turfgrass plants, leaf growth is inhibited. What happens to the rest of the plant?

One response, which we have measured, is tiller production. New tillers are produced in response to a PGR application. The data in Table 2 clearly show that leaf growth is inhibited first, and then,

beginning in week 4, tiller number increases. The data indicate a lag between the inhibition of shoot growth and tiller production, but is that really the case? We believe that tiller initiation begins at the same time leaf growth is inhibited. Because a new tiller is a complex structure that takes time to develop, the lag in time between shoot-growth inhibition and tiller emergence is probably just the amount of time needed for the tiller to become visible. The time from when the first cell of a new tiller is produced until the tiller emerges in the turf canopy is at least a two- or three-week process.

Thus, applying a growth regulator does not stop plant growth, it just redirects it. Some of the plant energy that would normally go into leaf production is transferred to new tillers. This response may also explain the rebound effect that can occur following a PGR application. As the PGR wears off, the turf often will produce more clippings than it would if no treatment had been applied. This response has been called a *rebound*. What causes the rebound effect? It may be that it is caused by the tillering response. If treating with a PGR results in more tillers at four weeks after treatment, then the rebound effect may largely be due to the contribution of these extra tillers to total leaf production. Continuing to apply a PGR will suppress leaf elongation and the rebound effect.

Therefore, applying a PGR that suppresses gibberellic acid production will cause an increase in tillering. What happens after several applications, or what effect does a PGR have when applied to an ultra-dense A-4 putting green mowed at 0.1 inch (2.5 millimeters)?

We haven't answered these questions, but we can speculate on the answers. Certainly, there is a theoretical limit to tiller density. A PGR application, or a series of applications, may push the community beyond the density it can normally attain under a given set of management conditions, but the closer the plant community is to maximum density, the less apparent the PGR effect on tillering will be. Under highly maintained turf conditions, such as a golf course green, we would not expect PGR applications to result in a significant increase in turf density.

The studies of the metabolism of two plant growth regulators in turfgrass were conducted at the Landscape Horticulture Research Center at the University of Illinois–Urbana-Champaign. **Photo by B. Branham**

Effects of PGR on leaf area and photosynthesis

We conducted experiments to determine the effects of PGR applications on leaf area and photosynthesis under field conditions.

Leaf area index

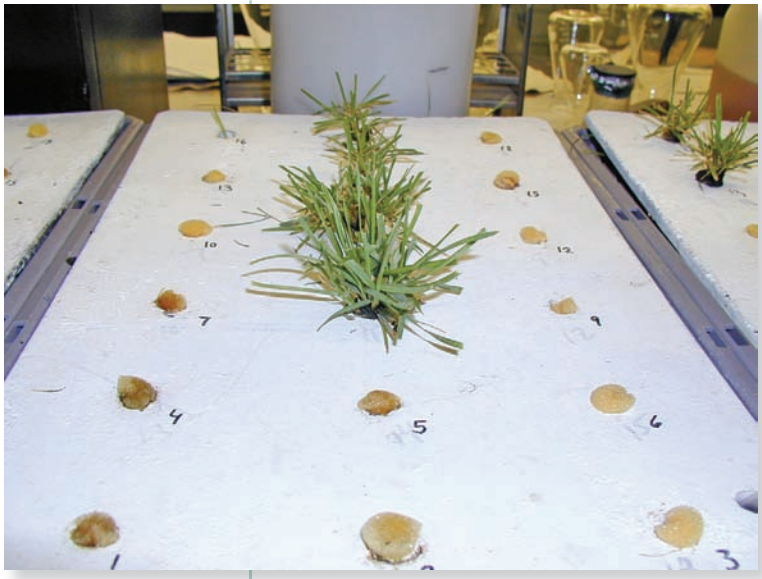
Leaf area index is an academic term that has some value for superintendents. It is a measure of the total leaf area divided by the land area that supported the leaves. A leaf area index of 2.0 means, for example, that 20 square centimeters

PGRs vs. leaf area indices

	Leaf-area indices — spring 2004			Leaf-area indices — summer 2004		
WAT	Primo Maxx	Trimmit 2SC	Control	Primo Maxx	Trimmit 2SC	Control
1	1.53*	1.47*	1.72	1.92	1.86	2.07
2	1.72	1.36*	1.63	1.98	1.72*	2.16
3	1.81	1.71	1.82	2.35	2.09	2.26
4	1.87	1.81	1.73	2.13	2.22	2.16
5	2.06	2.17*	1.91	2.18	2.24*	1.98
6	2.12	2.22	2.11	2.21	2.31	2.15
7	2.21	2.29	2.16	2.30	2.16	2.34
8	2.42	2.69	2.36	2.23	2.37	2.17

Abbreviation: WAT, weeks after treatment.
*The PGR treatment is significantly different from the control.

Table 3. Effects of Primo Maxx and Trimmit 2SC on leaf area indices of Kentucky bluegrass turf.



Growth chamber experiments compared the metabolism of both Trimmit 2SC and Primo Maxx in Kentucky bluegrass and creeping bentgrass. **Photo by J. Beasley**

of leaf area were collected from 10 square centimeters of land. The higher the leaf area index, the denser the turf.

In our study, we measured leaf area index weekly following PGR applications. Leaf area measurements were taken one week after mowing, and the effects of the preceding week's growth would be reflected in the measurements (Table 3).

For 2004, the only significant difference for Primo Maxx (when compared to the control) occurred at one week after treatment in the spring. All other measurements showed that treatment with Primo Maxx did not significantly change leaf area measurements. This reinforces the idea that treatment with Primo Maxx does not reduce growth, but redirects it. More leaf tissue is produced below the height of cut following treatment with Primo Maxx.

Trimmit 2SC, on the other hand, showed more activity. Leaf area was significantly reduced at weeks 1 and 2 in the spring and week 2 in the summer. Trimmit 2SC significantly increased leaf area at five weeks after treatment in both spring and summer. The differences between the two PGRs may be simply that Trimmit 2SC is more active than Primo Maxx, and the regulation and rebound effects are more pronounced, resulting in significant differences.

Photosynthesis

Finally, what is the impact of PGR application on plant photosynthesis? This is a key question because photosynthesis is the process that ultimately generates all plant growth. If a PGR reduced photosynthesis, that would imply that the PGR was reducing growth, but no reduction in photosynthesis would provide further evidence that PGRs redirect growth rather than reducing it.

Photosynthesis

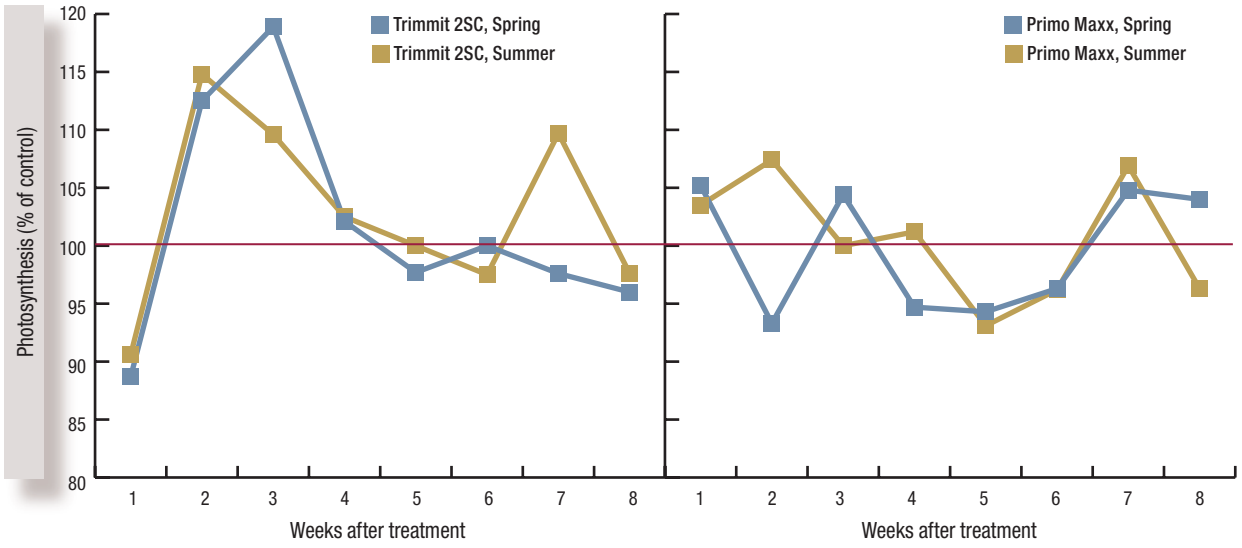


Figure 1. Turfgrass photosynthesis as influenced by Primo or Trimmit applied during the spring or summer. Data are presented as a percent of the control (untreated) turf. Values over 100 indicate that photosynthesis is occurring at a rate in the treated plant that is greater than the rate in the control plants.

We measured photosynthesis directly by covering a small portion of turf with a clear plastic chamber and measuring the amount of carbon dioxide used. The simplest measurement would be to measure carbon dioxide use per unit ground area. In other words, place the chamber over a small area of turf, make the measurement, and move on to the next measurement. The problem with this approach is that it assumes the leaf area under each chamber is the same. But as the above discussion on leaf area indicates, that is not a correct assumption. Both PGRs (particularly Trimmit 2SC) and biological variation among turfgrasses may affect leaf area. Thus, we decided that we needed to measure photosynthesis on a leaf-area basis to get an accurate picture of photosynthesis as affected by PGRs. Therefore, we placed the chamber on the turf to determine the carbon dioxide used in photosynthesis, removed the chamber, clipped off all the plants within the chamber, and measured the total leaf area.

The effects of PGRs on photosynthesis appear minimal (Figure 1). Primo Maxx had no effect on photosynthesis at any measurement time (Figure 1). Trimmit 2SC initially reduced photosynthesis at one week after treatment, but that reduction was statistically significant only in the spring. In addition, that apparent reduction was offset by a significant increase in photosynthesis at two and three weeks after treatment in both spring and summer.

The data indicate that these PGRs have minimal (Trimmit 2SC) to no (Primo Maxx) effect on plant photosynthesis. Thus, these products are true regulators and not growth retardants. Treatment with a PGR will increase tillering, but in the first week after application the turf will look less dense as leaf elongation is slowed and plant energy is redirected to tillering. The emergence and development of new tillers during the third and fourth week following application of a PGR will make the turf fuller and more dense.

Conclusions

PGRs have become widely used management tools that offer superintendents many benefits, including increased turf color, reduced leaf extension (and, therefore, reduced mowing), and increased density and uniformity. Having a better understanding of the effects of these PGRs will enable superintendents to make better use of these products.

Funding

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The research says

➔ Primo Maxx regulates most species to approximately the same degree, but Trimmit 2SC regulates Kentucky bluegrass for a longer period of time than it regulates creeping bentgrass.

➔ Trimmit 2SC and Primo Maxx are less active at higher temperatures; this is especially a problem for Primo Maxx, which disappears rapidly.

➔ When gibberellin-inhibiting PGRs such as Primo Maxx and Trimmit 2SC inhibit turf leaf growth, plant growth is redirected to tillering; continuing to apply a PGR will suppress leaf elongation and tillering.

➔ Primo Maxx did not significantly change leaf area measurements, but Trimmit 2SC significantly reduced leaf area in the spring and significantly increased leaf area at five weeks after treatment in spring and summer. Trimmit 2SC may be more active than Primo Maxx, making its regulation and rebound effects more pronounced.

➔ Because both these PGRs have minimal (Trimmit 2SC) to no (Primo Maxx) effect on plant photosynthesis, these products are true regulators and not growth retardants.