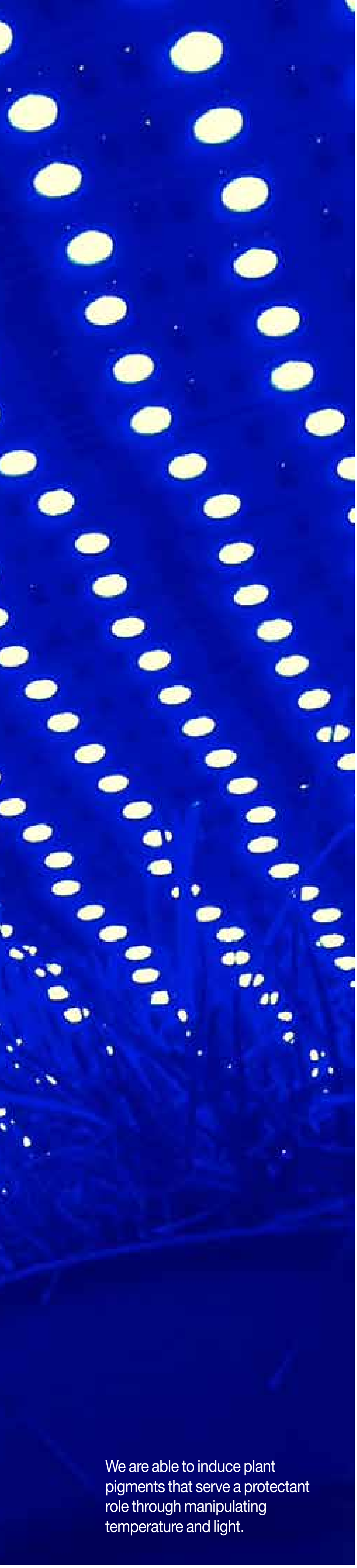
Pigments and photoprotectants in turfgrass

In a GI exclusive, three experts – including Dr Karl Danneberger who you can catch at the Turf Managers' Conference in January - look at the impact of pigments and photoprotectants in turfgrass



We are able to induce plant pigments that serve a protectant role through manipulating temperature and light.

about the authors

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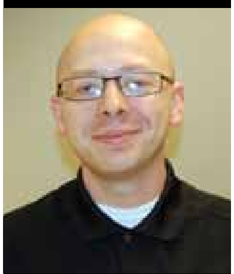

Dominic Petrella

Dominic Petrella has concentrated on Pigments and Dyes and their impact on turf at the same university.

As a brief review, solar radiation can be a two way street. In one direction the sun's energy is converted, by the plant, into a useable form of energy such as carbohydrates.

On the other hand, excess light energy can also overload the same photosynthetic system leading to physiological stress and decline (Demmig-Adams and Adams III, 1992). Therefore, light stress can ultimately impact turfgrass performance, wear tolerance, and even disease resistance. By limiting abiotic stress due to excess radiant energy, cool season turfgrasses may be better fit to withstand other biotic and abiotic pressures. From a light perspective, it's fairly well known that ultra-violet (UV) wavelengths of light are damaging to organic tissue, but plants visible light (PAR) also has the potential to be an abiotic stress (Hakala-Yatkin et al., 2010).

Light energy as a Stress

Cool season turfgrasses are photosynthetically limited by the quantity of carbon dioxide (CO_2) in the atmosphere. Because of this, turf species like Agrostis stolonifera and Poa annua can only utilise a given amount of light at a given amount of CO_2 (and temperature). Typically the amount of "useable" light intensity is around 400-500 µmols m2 s-1. When light intensities exceed these levels, plants are said to be photosynthetically saturated (Sharkey et al., 2010). To put it into perspective, light intensities during summer months will exceed 2,500 µmols m2 s-1 around midday. When levels of PAR exceed saturation, there is a high probability that the excess light will initiate chain reactions of oxidative stress leading to proteins, enzymes, membranes, and other molecules being degraded (Hakala-Yatkin et al., 2010). By relieving some light stress, we can potentially reduce physiological stress. The question is how can we decrease UV and visible light stress?

In theory, light stress as a whole can be mitigated by the application of photoprotectants (Kullavanijaya and Lim, 2005). These compounds have the innate ability to filter, absorb, and reflect damaging or excess light energy. Photoprotectants mimic the function of naturally occurring compounds that plants produce to filter and reflect light. Both the waxy cuticle layer and leaf hairs (trichomes) are constituent structures that function in reflecting UV and PAR light. However, when levels of light stress become excessive, many plants will induce the synthesis of extra quantities of carotenoids, anthocyanins, and flavonoids. These molecules are natural plant pigments that function in dissipating UV and PAR light that isn't blocked by the cuticle or used for photosynthesis (Demmig-Adams and Adams III, 1992).

Pigments

As of now, most products containing a photoprotectant that are used on turfgrass contain a class of compounds termed pigments. By definition a pigment must meet two criteria: it must be insoluble in its solvent, and it must absorb/transmit a given wavelength of light and reflect back a different wavelength(s) (Zolinger, 2003). What we see reflected by the pigment is "colour". The ability that pigments possess can be taken advantage of by serving as a physical barrier or screen to UV and PAR. When applied to the surface of a leaf, a pigment layer still allows for the transmission of PAR; however, PAR intensity will be decreased and the majority of UV light will be absorbed or reflected. A layer of pigment applied to a turfgrass surface will essentially serve as a shade, and in most cases this can be a good thing. For example, Poa annua is naturally a shade adapted species. Under full sun and low moisture, this turf will tend to show decline come summer (Beard, 1978). However, the application of a pigment may serve as an option for managing Poa annua outside of its adaptive range.

Several companies are promoting products that contain pigment. How do they differ? As far as the green pigment goes, there is no difference. The synthetic pigment used is a chemical derivative of a phthalocyanine (PC) molecule. These molecules are related to both porphyrins (chlorophyll) and hemes (hemoglobin), but structurally are considered to be more stable (Dahlem, 1939). Chlorinated-copper phthalocyanine, more commonly known as Pigment Green 7, is responsible for all of the green pigmented products currently in the turf market. However, Green 7 is widely used in many other fields. Organic photovoltaic solar cells take advantage of PC chemistry by using them to convert sunlight into electricity (Djurisic et al., 2002). The properties of PC's that allow it to convert light into electricity are termed photosensitization reactions. These chemical reactions are purposeful in some fields, but may impart problems when the pigment is applied to plant tissues.

When a pigment is photosensitive, it undergoes chemical reactions that either results in its oxidation (loss of electrons) or it will pass along high amounts of energy to nearby molecules (Abramcyzk et al., 2004). If placed on organic tissues many times this same process will result in the creation of reactive oxygen species (ROS). At this time, ROS production due to Green 7 applications has not been reported in plant tissue.

Green 7 is the only source of "colourant", but there are additional pigments being used in many products. For example, both titanium oxide (TiO) and zinc oxide (ZnO) are listed as active ingredients in Turf-Screen®. Both of these compounds are true pigments. However, their optical properties are different compared to Green 7, and their ability to reflect and absorb light are more dependent on the size and quality of the particles (Diebold, 2003). Even though these oxides are known for their high UV (and PAR) reflective capabilities, these properties will decrease as the size of the particle also decreases (Serpone et al., 2001). Kaolinite, a clay mineral, has been sold under the label Surround WP® as product to prevent and decrease sun scald on fruit/vegetable crops. Kaolinite can also be found in Daconil Ultrex®. Like both metal oxides, kaolinite is known to be able to reflect solar radiation; however, when compared to pigments like TiO and ZnO, less kaolinite is needed and the particle size is less important (Glenn et al., 2002).

Besides the type of pigment used, the other aspect that differentiates many pigment products is the deposition aid or sticker. These additives spread the pigment on the leaf and allow it to last for a longer period of time under variable weather conditions. Some common deposition aids that are combined with pigments include: silicon emulsions, synthetic latex, resins (plant terpenoids), silicon dioxide, metal oxides, and even oils (Hazen, 2000). Not only do stickers stick, but they also can physically decrease evapotranspiration (ET). Many superintendents claim less watering when certain pigment products have been applied. Decreased water use is not a property of the pigment, but instead is caused by the deposition aid physically blocking water loss (Gale and Hagan, 1966). In the short term lower ET rates can be helpful, but in the long run it could lead to other physiological dysfunctions.

And now for the most important question, do photoprotectants/pigments reduce turfgrass stress? Well – yes and no. One of the major factors in this decision is how we measure stress. The problem is many researchers measure stress in different fashions, and with different equipment. However, current research is showing that when Pigment Green 7 is applied in higher concentrations, it has the ability to slightly decrease light stress. Whether or not this decrease has any overall benefit is still questionable, but the research is starting to catch up and soon more answers should come available.

MAIN ABOVE: Pigments are being increasingly used as a replacement for winter overseeding warm season turfgrasses

LEFT: Besides being used to possibly protect turf or to decrease inputs, pigments can also be effectively used in late winter or early spring. For example, when coming out of winter Poa annua may be discolored or injured. Spraying a pigment can help provide green cover prior to new growth taking over.

INSET LEFT: A factor overlooked when discussing pigments and light protection is leaf coverage. Looking at this image, less than approximately 20% of the leaf in focus is coated in pigment. If the pigment provides some photoprotection, without adequate coverage (approx. ≥50%) more than likely there will not be a whole plant benefit. Pigment products may need optimized in terms of chemistry and application technique before any true decrease in stress can be measured.

BELOW MIDDLE: Some pesticides have the potential to cause unwanted discolouration. Many of these products may be essential, but the associated phytotoxicity will cause some superintendents not to use them. Applying a pigment before, mixed, or shortly after the pesticide has been sprayed can prevent the discoloration from showing through. The pigment doesn't have any effect on the efficacy of the pesticide, but using pigments in this fashion allows more options when choosing pesticides.

BOTTOM LEFT: Many pigment products produce vastly different colours when sprayed. The final colour on the turf can be affected by a variety of factors. The concentration of pigment green 7 and the type of additional additives in the product both play a role on how the pigment will look when sprayed. It's important to spray the pigment over a test area to determine if the rate you're using provides the colour you're looking for. Many pigments only have a suggested rate, so the rate should be adjusted to reach the desired colour.

BELOW: Rather than overseed bermudagrass in the fall, may superintendents have turned to painting. Painting dormant warm season turf can decrease costly inputs, while still maintaining a visually appealing turf. However, many question if pigments should be applied to warm season grasses outside of dormancy. The answer is no. Warm season plants rarely, if at all, are stressed by high light intensity. UV light may still be damaging, but these grasses are more adapted to handle UV light. The shade the pigment provides could end causing more harm than good on warm season turf. Using pigments outside of dormancy should be avoided at all costs.

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