BY ERIK H. ERVIN, PH.D.

Surviving summer

A seaplant extract-based foliar nutrition program might improve stress tolerance

Given prolonged stress, root tip cytokinin production will decline sharply, resulting in little or no cytokinin xylem transfer to leaves. Adequate leaf tissue cytokinin levels signal the plant to keep producing antioxidants and resist senescence (or programmed cell death). Once leaf tissue cytokinin levels fall, antioxidant production isn't maintained, and programmed cell death (and accompanying translocation of energy reserves to crown storage tissues) is allowed.

How can we intervene and forestall this decline? First, we can fine-tune our irrigation, mowing, cultivation and fertilization practices so as to produce as robust a plant as possible (within the demands of your budget and clientele) before the summer stress season. A balanced, but not overzealous, nutrition program is a must, and True Foliar nutrition appears to offer the right balance.

Second, application of a university-tested biostimulant based on cytokinin-containing seaplant extracts before the onset of summer stress might help forestall decline.

FOLIAR FERTILIZATION

Bob Carrow, Ph.D., and others define foliar fertilization as the application of a nutrient solution in a low volume of water (less than one gallon per 1,000 square feet or 40 gallons per acre). Typically 95 to 100 percent of the water and nutrients remain on the foliage and are able to move into the leaf apoplasm through cuticle and stomatal pores.

Application of nutrient solutions at higher water volumes (three to 25 gallons per 1,000 square feet) as done by liquid lawn care companies and with fertigation isn't considered to be true foliar fertilization because these higher application volumes function to wash most nutrients off the leaf surface, resulting in nutrient uptake by shallow roots.

When open, stomatal pores are greater than 10 micrometers, while cuticular pores are 1,000 times smaller at 1 nanometer or less. Urea (COH_4N_2) in solution, for example, has a radius of 0.44 nanometer and is uncharged making foliar uptake quite fast. Thus, smaller molecules such as ammonium (NH_4^+) and nitrate (NO_3^-) will be absorbed foliarly but at different rates because of their charge differences.

For example, D.C. Bowman and J.L. Paul (1992) reported that foliar application of three nitrogen sources to perennial ryegrass resulted in about 40 percent urea and ammonium uptake after 24 hours, while only 25 percent nitrate was absorbed. Synthetic chelates, such as FeEDTA, are much larger molecules and will be excluded from cuticular pore uptake but not stomatal uptake. Organic chelates, like ferrous citrate, most likely will allow cuticular pore uptake because they're much smaller molecules.

The cuticle consists mainly of cutin, a mixture of long-chain fatty acids. The outer surface of the cuticle is hydrophobic, while the inner surface is more hydrophilic. Cuticular pores are lined with fixed negative charges (mainly from polygalacturonic acids)

Seaplant extract contains cytokinin, which contributes to heat- and drought-stress resistance. Photo: Nick Seaver increasing in density from the outside of the cuticle to the inside. Accordingly, cation permeability along this gradient is enhanced whereas anions are repulsed from this region, but not completely excluded as seen with the Bowman and Paul data mentioned above.

What about cuticular pore uptake of phosphorus, potassium, and micronutrient sources? Ingredients such as potassium citrate and potassium acetate will most likely disassociate in water, leaving potassium to move easily into the leaf. The same is true for manganese citrate, zinc sulfate, copper sulfate and ammonium polyphosphate. Thus, the textbook evidence indicates mineral elements can be absorbed by foliage successfully.

So what's the fate of mineral elements that aren't absorbed by the foliage? In the case of foliarly applied urea, for example, Wesely and others (1987) reported about 30 percent was volatilized as ammonia during the four days following application. In a two-year field study, Miltner and others (1996) estimated about 20 percent of nitrogen from applied urea was lost to volatilization, while about 38 percent was found in clippings, and 40 percent was immobilized in soil and thatch layers.

Reducing potential volatilization and immobilization are areas where nitrogen-use efficiency could be increased due to proper formulation and foliar fertilizer use.

Proper formulation of foliar sources to decrease potential nitrogen volatilization and nitrogen immobilization would involve applying nitrogen sources that are most readily foliarly absorbed – urea and ammonium – and are recommended to be applied at a concentration (0.05 to 0.20 of a pound of nitrogen per 1,000 square feet) and volume (one gallon per 1,000 square feet) low enough so as not to overload the leaf's capacity to absorb them during a 24-hour period.

Less ammonia volatilization will occur because small rates of urea and ammonium are absorbed readily through pores and not left on the leaf surface for urease to convert urea

Adequate cytokinin levels in leaf tissue signal plants to keep producing antioxidants and resist programmed cell death. Photo: Virgina Polytechnic Institute and State University

to ammonia. Furthermore, less soil/thatch immobilization of nitrogen will occur because less nitrogen will be available to be washed from the leaf surface by rainfall or irrigation. Of course some irrigation or rainfall washing of nutrients from the leaf surface will happen, but the small concentrations reaching the surface soil solution most likely will be effectively root absorbed, again leaving little nitrogen to be immobilized and stored in soil organic matter or microorganisms or to be leached.

However, a potential drawback to such efficient use of foliar nitrogen might be no stored organic pool of nitrogen to be released by microbial mineralization following cessation of the summer foliar fertility program (as Richardson's research indicated). Supplementing foliar fertilization with a sound spring and fall granular program will easily overcome this limitation.

Is there any experimental data that indirectly supports the above reasoning concerning greater nutrient use efficiency? Putting it another way, can fewer overall nutrients be applied, compared to conventional approaches, and still provide equivalent or better summer bentgrass performance? Two recent studies are helpful in answering these question.

Frank Rossi, Ph.D., (Cornell, 2003 bioproducts comparison trial) conducted a trial from June through November comparing the Emerald Isle seaplant extract greens nutrition program to a standard water-soluble synthetic spoon-feeding program. The standard program plots received 0.1 pound of nitrogen per 1,000 square feet every seven days plus granular fertility, while the seaplant extract based foliar program plots received 0.1 pound of nitrogen every 14 days: a 77 percent nitrogen reduction during the season on this Penn G2 green mowed at 0.100 inch. In spite of the significant difference in nutrient inputs, equivalent quality was maintained with the foliar program.

Mike Richardson, Ph.D., (Arkansas, reduced

Sea plant extract is linked to stress tolerance because it contains cytokinin, which increases a plant's pool of antioxidants, boosting its immune system. Photo: Nick Seaver

summer nutrient input study on a four-year-old sand-based Crenshaw bentgrass green) compared a four-pound nitrogen program (standard slow-release synthetic and natural organic sources) with a 1.5-pound nitrogen seaplant extract based Emerald Isle foliar nutrition program. Quality was high for both programs with no significant difference between the two. However, clipping yields and thatch accumulation were reduced with the Emerald Isle programs, which is typically correlated with better putting conditions.

SEAPLANT EXTRACT DATA

Before 2004, we published numerous studies documenting increased antioxidant content and, subsequently, greater drought or heat tolerance due to prestress foliar applications of seaplant extract (see references online). However, we had yet to tie antioxidant increases to increased leaf tissue cytokinin levels. In 2004, we published the results of a creeping bentgrass (L-93, Penncross and Penn G-2) drought experiment that provided evidence supporting our supposition that cytokinins in the seaplant extract will result in greater leaf tissue cytokinins, antioxidants and quality under drought.

The seaplant extract used in the study on page 87 contained 70 micrograms per gram cytokinins (zeatin riboside plus isopenteyl adenosine). Leaf tissue levels are 10^{-3} lower than that present in the extract spray solution. Hormones act in minute concentrations (a nanogram equals 10^{-9}), and it takes only a slight increase to have an effect of metabolic significance.

We have quantified the level of the predominant cytokinin, zeatin riboside, present in the product used (CPR) on two occasions. Those levels were: 90.2 and 127.1 micrograms per gram. We measured a zeatin riboside level of 80.0 nanograms per gram in greens-height bentgrass leaf tissue following six summer 2003 applications. No heat or drought stress occurred during this field trial, so we didn't get to observe whether this elevated cytokinin level would have provided greater stress resistance. However, it appears the leaf tissue was primed for action.

In a study completed in 2003, we also quantified the difference in levels in leaf tissue cytokinins between a standard soluble fertility program and the Emerald Isle seaplant extract based foliar nutrition program. With comparable levels of nitrogen inputs (.09 pound of nitrogen per 1,000 square feet every 14 days), the Emerald Isle program produced significantly greater cytokinin levels (zeatin riboside) in late July and August.

CYTOKININS AND STRESS TOLERANCE

Hormones are defined as plant-synthesized compounds that, in very low concentrations, cause a physiological response or regulate growth and development. In other words, hormones are one of the necessary compounds that must be present in a specific tissue, at the right concentration, to allow a certain metabolic (or growth) event to occur. Additionally, each hormone doesn't operate in a vacuum, as it's the concentration ratio of one hormone class relative to another that determines which developmental or metabolic event occurs.

For example, auxin and cytokinins induce cells to divide so new roots and shoots can be initiated, but their ratio determines priority. Thus, it's well documented that a higher ratio of cytokinins to auxin in meristematic (crown) regions promotes tillering (or shoot development), while root initiation lags behind. However, a higher ratio of auxin to cytokinins in the same tissue will result in greater root initiation at the expense of tiller formation.

The key moment in all this comes when we consider where in the plant each of these hormones are produced primarily: Cytokinins are produced in new, viable root tips, while auxin is produced in new shoots. Thus, if the plant has enough healthy roots, enough cytokinins will translocate from the root tips to the crown and shoot tissue and serve as the signal to say: "We're doing OK down here, so go ahead and use some energy to increase shoot density."

Correspondingly, if enough healthy new shoots are being produced, more auxin will translocate to the crown and serve as the signal to say, "We're doing OK up here, but we need to use some of our energy (photosynthate) to initiate and grow some roots to continue supporting this growth."

Obviously, this is simplified, but it clearly makes the point: Lower cytokinin amounts coming to the crown serve as a direct feedback signal – don't grow new tillers at the expense of existing root viability.

Alternatively, heavy mechanical or pest damage on the surface will result in less auxin moving to the crown, thereby changing the balance to favor cytokinins, which will result

Tips for efficient foliar fertilizer uptake

- **Apply between 7 a.m. and 1 p.m. when stomates are most open.**
- **Apply to turgid or nonwater stressed leaf tissue as the intercellular solution (apoplast) will be more dilute creating a greater diffusion gradient for nutrient absorption and cuticle waxes will be thinner.**
- **Do not water in as this will wash the minerals from the leaf surface.**

Antioxidants reaction sequence

1. $O_2^- + O_2^- + 2H^+ \xrightarrow{SOD} H_2O_2 + O_2$
2. $H_2O_2 \xrightarrow{catalase} H_2O + \frac{1}{2} O_2$
or
3. $H_2O_2 + \text{ascorbate} \xrightarrow{APX} 2H_2O + \text{dehydroascorbate}$

in more tiller initiation to replace those tillers being lost.

There are other important points about cytokinin function. Cytokinins have been shown to operate not only as chemical signals to allow or disallow certain developmental events, but to act directly as antioxidant and antisenescence chemicals. The stress resistance message here is that higher leaf tissue levels of cytokinins are overwhelmingly correlated with longer maintenance of functioning (photosynthesizing) green leaves that contain higher levels of antioxidant vitamins (E and C) and antioxidant enzymes (SOD, CAT, APX) when subjected to heat and drought stress. Refereed papers in Crop Science and HortScience authored independently by Bingru Huang and me provide replicated data that confirm the above statements.

OK, what does all of this have to do with summer stress? A brief walk-through of the oxidative stress cycle that occurs in response to summer heat, drought, mechanical and disease stresses should provide some answers. Plants possess antioxidant defense systems that function to protect cells against damage. This system needs to be operating under all conditions, stressful or not.

A natural consequence of radiant (light) energy hitting leaf surfaces is that some of this energy will be absorbed by chlorophyll and excite an electron to move through the photosystems and serve as the fuel for turning light energy into chemical energy. Other excited electrons won't be transferred in this manner and will react with oxygen in the chloroplast to produce reactive oxygen species (or free oxy-radicals) such as superoxide (O_2^-).

A robust pool of antioxidants in the chloroplast are always required to deactivate free radicals such as superoxide and hydrogen peroxide (H_2O_2) or else membranes and other essential organic molecules will begin to be destroyed. The antioxidants required for protection and their reaction sequence are listed above.

Superoxide dismutase (SOD) – as shown in equation one – is required to turn superoxide radicals into hydrogen peroxide and ground-state oxygen (equals good or nonreactive oxygen). However, hydrogen peroxide (bleach), as we know, is quite a dangerous, reactive substance. The plant has two antioxidant enzyme systems to deal with hydrogen peroxide. Catalase – as shown is equation two – will convert some to water and oxygen, while ascorbate (or vitamin C) will react with some and, with the help

Demand for fast and firm drives foliar feeding

BY PAT JONES

Ask any low-handicapper what kind of conditions he wants at his club or regular course, and the response is predictable: fast and firm.

Fast and firm have become buzzwords among avid golfers. They usually can't define what they mean by the term, but they know they want it. It's like art: They don't know much about it, but they know what they like.

As superintendents strive to meet that vague but compelling demand for fast and firm, they've increasingly sought to reduce the amount of nitrogen they use to eliminate puffiness and other side effects of traditional N-based fertility programs. Thus, foliar feeding – which just a decade or so ago was considered by many to be tantamount to snake oil – has emerged as a huge trend in the business.

Foliar feeding is rarely a one-shot deal, although foliar products are often used as tank-mix supplements for plant growth regulators or fungicides. Instead, foliar nutrition products usually are packaged in programs based on needs determined by soil testing and local conditions. Some programs require careful calculation and measurement. Others, like the one described in the above article, have simplified the process to help reduce the possibility of misapplication by packaging product in premeasured doses.

Typical programs are based on a core product – usually a seaplant extract, amino acid or other nutrient source – plus smaller amounts minerals like magnesium, calcium or iron. Again, the recommended combination of products needs to be based on an objective analysis of turf and soil needs determined by lab testing.

Foliars once were considered to be a luxury item reserved for high-end facilities; but, over the years, pricing has declined and superintendents have recognized they can – with the right program – realize savings in terms of fungicide applications and other curative measures that might be required when low-nitrogen turf becomes stressed out.

That said, foliar programs can be a sticker shock for a facility used to relatively cost-effective traditional fertilization programs. A full foliar program can run anywhere from $5,000 to $30,000 a year, depending on which product is used and whether fairway applications are part of the system. Clearly, those costs have to be weighed against the agronomic benefits and potential chemical savings.

Golfers – despite the best efforts of golf organizations and superintendents – will continue to demand fast and firm conditions and wall-to-wall green color.

The right foliar program can be more expensive but can meet those expectations. The best advice: Do your homework, talk to colleagues and reps and make sure you've chosen wisely before you make the jump into foliar feeding.

SEAPLANT EXTRACT INFLUENCE

End-of-trial average creeping bentgrass responses as influenced by seaplant extract (5 grams dry weight per 1,000 square feet) under the presence or absence of drought stress.

Response	Drought stressed (5% soil moisture)		Well watered (35% soil moisture)	
	Untreated	Seaplant extract	Untreated	Seaplant extract
Quality (9=best)	4.4	5.5*	7.9	8.4*
Photosynthetic efficiency	0.23	0.30*	0.66	0.68
Shoot weight (grams)	0.96	1.46*	5.27	5.56
Root weight (grams)	0.59	0.69	0.86	0.91
Vitamin E (micrograms per gram)	10.7	14.3*	2.1	3.7*
Zeatin riboside (nanograms per gram)	18.3	28.9*	19.4	27.1*

* Indicates a significant difference from the untreated at a 95 percent level of probability.
Data compiled from Xunzhong Zhang and Erik Ervin. Crop Science 44:1737-145 (2004).

of ascorbate peroxidase (APX) – as shown in equation three – convert it to water and dehydroascorbate. The dehydroascorbate then, in a short series of reactions, cycles back to ascorbate. The production of these antioxidant enzyme proteins requires plant energy.

Heat and drought stress greatly increase free radical production. Initially, plants respond by increasing production of antioxidants to protect photosynthetic function. However, if the assault is persistent antioxidant pools will become depleted and substantial leaf senescence will occur as the plant stops all leaf growth and new root development and conserves energy reserves in the crown and surviving roots.

As mentioned earlier, cytokinins are produced in the tips of relatively new and viable roots. Given prolonged stress, root tip cytokinin production will decline sharply, resulting in little or no cytokinin xylem transfer to leaves. Adequate leaf tissue cytokinin levels signal the plant to keep producing antioxidants and resist senescence (or programmed cell death). Once leaf tissue cytokinin levels fall, antioxidant production isn't maintained and programmed cell death (and accompanying translocation of energy reserves to crown storage tissues) is allowed.

How can we intervene and forestall this decline? First, we can fine-tune our irrigation, mowing, cultivation and fertilization practices so as to produce as robust a plant as possible (within the demands of your budget and clientele) before the summer stress season. A balanced, but not overzealous, nutrition program is a must, and True Foliar nutrition appears to offer the right balance. Second, application of a university-tested biostimulant that is based upon cytokinin-containing seaplant extracts before the onset of summer stress might help forestall decline.

How? Our research-backed reasoning is that by purposefully boosting leaf tissue cytokinin levels and, in turn, increasing the plant's pool of antioxidants, the plant can fight off (or deactivate) stress-induced free radicals for a longer period of time. The result is a boosted immune system that prolongs photosynthetic efficiency, allowing for a minor amount of sustained energy production and maintenance of leaf and root tissue viability during summer stress. Of course given prolonged stress, even plants with boosted immune systems will succumb and die.

The point isn't that these programs will create a supergrass, but they might provide a little added insurance during the summer, especially during the member-guest tournaments when you're asked to double-cut at 0.095 inch, roll and not irrigate or syringe. **GCI**

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Editor's note: References for this article can be found online at www.golfcourseindustry com.

BY MICHAEL AGNEW, PH.D., AND MICHAEL FIDANZA, PH.D.

A manageable process

A solutions-based approach to disease control on *Poa*/bentgrass greens in the Northeast

Developing an effective disease control program for golf course turf requires a multifaceted approach. If superintendents break down the process into four steps, the process becomes manageable. This process should be done separately for greens, tees, roughs and fairways. Disease control of a mixed stand of creeping bentgrass and annual bluegrass on established greens is a solutions-based approach that can be applied to any turfgrass species on any part of the golf course. It's also a proactive way to keep a course disease free.

STEP 1: IDENTIFY TURFGRASS SPECIES.

The first step in the development of any disease control program is to identify the turfgrass species and to understand its strengths and weaknesses. The majority of golf course greens in the Northeast are a mix of annual bluegrass and creeping bentgrass.

Annual bluegrass can be found on all parts of a golf course as a winter annual weed (*Poa annua* var *annua*) or a weak perennial type (*Poa annua* var *reptans*). Annual bluegrass is a shallow-rooted plant that survives under adverse growing conditions and will produce copious amounts of seedheads from early April through June. This process channels much of the stored carbohydrates to the production of seedheads at the expense of root production.

It's possible to grow annual bluegrass as a desirable plant species, especially if the bulk of the annual bluegrass population is a perennial biotype. The strength of annual bluegrass is in its ability to adapt to poor growing conditions such as low mowing heights, compacted soils, low soil nitrogen and traffic. So, to maintain annual bluegrass as a desirable plant species, it's important to minimize mechanical and environmental stresses to the plant. While superintendents might not have control over all imposed stress, such as excessive rainfall or extremely high temperatures, they can control management practices to reduce environmental stresses.

Creeping bentgrass (*Agrostis stolonifera*) can be established on greens, tees or fairways. Within this plant species, there are many cultivars that have a wide genetic diversity. The most commonly used cultivar is Penncross. It was developed during a time when mowing heights were higher and emphasis on green speed wasn't as great. Newer high-density cultivars have a greater tolerance for lower mowing heights, thus a better choice for newly established greens. In general, creeping bentgrass is tolerant of cold temperatures but prone to winter desiccation. Creeping bentgrass also has poor shade tolerance, low soil O_2 levels and builds up thatch quickly. The primary quandary growing creeping bentgrass is the relative ease with which annual bluegrass invades the turfgrass stand. This forces superintendents to decide whether to control annual bluegrass or manage it on a golf course.

The key to controlling diseases such as summer patch is to know how and when conditions favor their development. Photo: BASF

STEP 2: IDENTIFY KEY MANAGEMENT FACTORS THAT INFLUENCE DISEASE DEVELOPMENT.

The primary management factors that influence disease development on a *Poa*/bentgrass green include mowing, plant nutrition, cultivation, topdressing, seedhead control, irrigation and herbicide applications.

The effects of mowing on disease development can be enormous. To maintain acceptable playing conditions, mowing is a necessary physical stress on the turfgrass plant. If possible, raising mowing heights during periods where weather conditions are conducive to disease development can reduce disease significantly. The mowing height range for annual bluegrass greens is 0.15 to 0.25 inch. Mowing heights for creeping bentgrass range from 0.08 to 0.20 inch, with cutting heights of 0.125 or less for newer, high-density cultivars.

Double cutting, rolling and turf grooming also can encourage disease development. Double cutting increases wounding of the plant and soil compaction and wear, providing a point of entry for pathogens. If done too often, lightweight rolling also can increase soil compaction and wear, but rolling three times or fewer each week will increase greens speed without significantly impacting the soil. Grooved front rollers lead to increased wounding and should be avoided when anthracnose is active.

Maintaining sufficient nutrients to the turfgrass plant can improve plant quality and reduce disease development. While all plant nutrients are essential, nitrogen is the most important by far when it comes to plant vigor. It's essential to provide adequate nitrogen to maintain a healthy, vigorous plant that can defend itself from infection. The amount of nitrogen will vary by site and with weather conditions. Sandy sites require greater amounts of nitrogen than heavier soils such as clays. Turf grown under dry conditions requires less nitrogen than turf growing under wet, warm conditions. Typical nitrogen rates will vary between 0.1 and 0.3 pound per 1,000 square feet. While appropriate levels of nitrogen are important, superintendents should avoid excessive nitrogen because this can lead to other problems such as poor surface quality, increased thatch and increased wear damage.

Cultivation practices are important tools for alleviating soil compaction and thatch. Superintendents should avoid summer cultivation practices that cause excessive plant wounding. A wounded plant will be more susceptible to attack by an opportunistic pathogen such as *Colletotrichum graminicola*, the causal agent for anthracnose.

Topdressing is used to reduce thatch and to provide a smooth, firm putting surface, but the topdressing process can result in plant injury, especially if the topdressing material is applied heavily and brushed in. If done during periods of high temperature stress, the abrasion of the topdress and associated processes can result in elevated levels of anthracnose.

Plant growth regulators and herbicides are used often to reduce annual bluegrass seedhead development. It's important to begin a fungicide program before applying PGRs to avoid injury and discoloration. Recent research also suggests increased anthracnose could result from the application of plant growth regulators.

Irrigation also influences the health of a turfgrass plant, and it's important to maintain a soil profile that's not too wet or too dry. This can be tricky during extremely wet years and droughts. To reduce disease activity, syringe the turf when soil temperatures are greater than 75 F. To avoid wilt stress, greens might need to be syringed several times during the late afternoon, typically from 10 a.m. to 5 p.m.

When developing a disease control program, it's important to understand adverse plant reactions to other plant protection products. Specifically, care should be taken when using preemergent herbicides on annual bluegrass stands. Many preemergent herbicides caution against use on desirable annual bluegrass. If using a preemergent herbicide, a strong fungicide program should be initiated before application.

STEP 3: IDENTIFY POTENTIAL DISEASES.

Many plant diseases attack annual bluegrass and creeping bentgrass, but some target one plant species or the other. In an established mixed

It's a science ... and an art

BY PAT JONES

Last month, I went to Lubbock, Texas, to give a speech to the West Texas GCSA. I talked with a dozen or so superintendents from the area and found that – although they often suffer from drought-related problems, fire ants, desert weeds and other problems typically associated with their part of the world – they rarely have to deal with disease.

Until this year, that is. Following an unusually wet spring, some courses were finding those nasty yellowish spots on greens. In some cases, it looked like take-all patch. In others, it could have even been pythium. A couple of guys told me it was the first time they'd sprayed fungicides in years. A few at higher-end facilities even said they had to spray monthly. Imagine that.

For a Yankee like me, it was interesting to hear about a different world of disease management where, in the worst case scenario, a 30-day application schedule was necessary for three or four months. Compare that to most of the rest of the golf world where two weeks is pushing the edge of the envelope. Such are the demands of growing plants at less than $1/8$ of an inch.

The article above describes a simple, four-step approach to establishing a sound disease management program. It's a good framework that allows you to examine or reexamine the foundations of your control efforts.

However, the science of disease management has to be combined with the art of greenkeeping to be successful. As the authors point out, weather patterns, cultural practices and changes in disease patterns need to be part of the equation as well.

But, keeping an ear to the ground is perhaps one of the most important parts of the art in the process. Comparing notes with neighboring superintendents, local reps and manufacturer's reps can be invaluable as well.

It's not unusual for fungicides to be the largest nonlabor expense in a golf course maintenance budget. Figures from a few years back suggest the national average spending for fungicides is about $22,000 per course. That includes facilities like those in west Texas and other parts of the West where disease pressure is nearly nil. So, it's not uncommon to find Northern private clubs spending $50,000 or more – in some cases way more – on disease management. It's simply the price most need to pay for stress-free turf.

It might sound overly simplistic, but disease management is the trickiest and most expensive part of the art and science of golf course maintenance. Thus, it should require the most thought and examination. By using a simple approach as described in the article above, you can bring a little more science to the art ... and maybe even sleep better.

An example of a programmatic approach for turfgrass disease control compared with single products

FUNGICIDE	RATE	PERCENT DISEASE		TURFGRASS QUALITY	
	AMOUNT OF PRODUCTS PER 1,000 FT²	JULY 20, 2005	AUG 18, 2005	JULY 20, 2005	AUG 18, 2005
SYNGENTA PROGRAM*	SEE BELOW	6.3	0.4	7.0	7.8
CLEARY'S 3336	4.0 OZ	22.5	3.5	5.5	6.5
DACONIL ULTREX	3.2 OZ	12.5	1.6	6.3	6.3
BANNER MAXX	1.0 FL OZ	13.0	1.1	6.3	6.3
UNTREATED		41.3	11.2	5.0	4.5

Data from efficacy trial conducted at Bethlehem (Pa.) Municipal Golf Course (Fidanza, 2005)

* Syngenta Program (all rates are based on amount of product per 1,000 square feet applied at 14-day intervals)
Application 1: Banner Maxx 2 fl oz., Daconil Ultrex 3.2 oz., Primo Maxx 0.125 fl oz.
Application 2: Medallion 0.25 oz., Daconil Ultrex 3.2 oz., Primo Maxx 0.125 fl oz.
Application 3: Heritage TL 2 fl oz., Banner Maxx 1 fl oz., Daconil Ultrex 1.8 oz., Primo Maxx 0.125 fl oz.
Application 4: Medallion 0.25 oz., Banner Maxx 1 fl oz., Daconil Ultrex 1.8 oz., Primo Maxx 0.125 fl oz.
Application 5: Heritage TL 2 fl oz., Subdue Maxx 1 fl oz., Daconil Ultrex 3.2 oz., Primo Maxx 0.125 fl oz.
Application 6: Medallion 0.25 oz., Banner Maxx 1 fl oz., Daconil Ultrex 1.8 oz., Primo Maxx 0.125 fl oz.
Application 7: Heritage TL 2 fl oz., Subdue Maxx 1 fl oz., Daconil Ultrex 3.2 oz., Primo Maxx 0.125 fl oz.
Application 8: Medallion 0.25 oz., Banner Maxx 1 fl oz., Daconil Ultrex 1.8 oz., Primo Maxx 0.125 fl oz.
Application 9: Cleary's 3336 4 oz., Daconil Ultrex 1.8 oz., Primo Maxx 0.125 fl oz.

stand of annual bluegrass and creeping bentgrass, primary diseases will be anthracnose, dollar spot, brown patch, leaf spots, Pythium blight and summer patch. The key to controlling these diseases is to know how and when conditions favor their development.

Anthracnose is most destructive during warm weather but can occur at any time of year. It causes irregularly shaped patches that range from yellow to brown in color. Leaf lesions that are yellow with black centers might also occur. Anthracnose also causes a basal stem rot from late winter to fall. Infected shoots are detached easily. Dead foliage and stems become covered with acervuli – tiny, spined, black fruiting bodies.

Anthracnose development is favored by temperatures warmer than 78 F. It occurs in areas that experience more than 10 hours a day of leaf wetness for several consecutive days. Soil compaction, low mowing heights and low amounts of nitrogen fertility also contribute to this disease.

Dollar spot causes sunken, circular patches that measure as wide as two inches in diameter on golf greens and several inches on higher turf heights. The patches turn from brown to straw in color and might eventually coalesce, forming irregularly shaped areas. Infected leaves might display small lesions that turn from yellow-green to straw color with a reddish-brown border. The lesions can extend the full width of the leaf. Multiple lesions might occur on a single leaf blade.

Dollar spot is favored by temperatures between 59 F and 86 F and continuous high humidity. Warm days, cool nights and intense dews particularly contribute to this disease. It infects areas with low levels of nitrogen and becomes more severe in dry soils.

The symptoms of brown patch can vary depending on the grass cultivar, climatic and atmospheric conditions, soil and intensity of turfgrass management. This disease typically causes rings or patches of blighted turfgrass that measure from 5 inches to more than 10 feet in diameter. It also causes leaf spots and "smoke rings" – thin, brown borders around diseased patches that appear most frequently in the early morning dew. After the leaves die in the blighted area, new leaves can emerge from the surviving crowns.

High relative humidity and temperatures of warmer than 85 F during the day and 60 F at night favor brown patch. It also occurs in areas that experience more than 10 hours a day of foliar wetness for several consecutive days.

Leaf spot (melting-out) causes purplish-brown to black spots with tan centers on the leaf blade and sheath. Leaf spot favors temperatures between 40 F and 80 F. It occurs in areas that experience more than 10 hours a day of foliar wetness for several consecutive days and also favors high amounts of nitrogen and low mowing heights. Lower leaves of infected plants become shriveled and blighted. When infection is severe, almost all leaves and tillers die, causing severe thinning of the stand or melting-out. On cool-season turfgrasses, melting-out typically follows the appearance of leaf spots.

Pythium blight appears suddenly during hot, humid weather. It's common in the wettest areas of turf, such as drainage patterns. This disease causes greasy, brown circular spots that are initially about 3/4 inch to 2 inches in diameter and then rapidly enlarge in size. The spots are water-soaked and dark-colored early in the morning. They also form fluffy white masses of fungal mycelium (cottony blight) and can coalesce to form large, irregular areas of dead turf. Infected patches might appear bronzish-orange in color.

Pythium blight is favored by night temperatures warmer than 68 F. It occurs in areas that experience more than 10 hours a day of foliar wetness for several consecutive days. It's found in areas with poor drainage and air circulation as well as in locations that are high in nitrogen.

Summer patch is a root disease. It appears as circular or irregularly shaped patches that measure from several inches to several feet in width. The patches are bronzish-yellow to straw-colored and can coalesce as they increase in size. The leaves of the plant turn yellow to brown from the tip to the base. The roots turn moderate to dark brown. Summer patch can also cause frog-eye – a symptom in which a less susceptible grass survives inside the diseased patch.

Root infection is initiated when soil temperatures at a 2-inch depth exceed 65 F. Foliar symptoms of summer patch occur six to eight weeks after root infection begins and are favored by temperatures warmer than 85 F during the day and warmer than 70 F at night. It's also commonly found in areas with alkaline soils, high soil moisture, compaction, poor drainage and low mowing height. This disease is typically more severe in turfgrass that has been fertilized with nitrate-nitrogen.

STEP 4: MAP OUT THE POTENTIAL TIMES FOR DISEASE PRESSURE AND FUNGICIDE APPLICATIONS.

After the diseases requiring control has been identified, the next step is to map the potential times for disease pressure. Typically, history is the best guide. There are tools that offer historical data to help determine these times.

The mapping process is done by creating a series of boxes representing each month of the year and marking them accordingly. In months where disease activity frequently occurs, the box is colored green. In months where disease activity occasionally occurs, the box is colored yellow. If disease rarely occurs during a month, the box is left uncolored. This practice helps superintendents visualize the development of a disease control program.

Next, place a star in the month when you plan to make a fungicide application to control the particular disease.

This process should be done for each disease on your list. The final step is to create a spray schedule that accomplishes all that is mapped out. In creating a schedule, list all fungicides that will control each disease. Look for broad-spectrum fungicides that control multiple diseases, as this increases efficiency of fungicide applications.

Once the program is committed to paper, it's easy to add other scheduled management practices. One that shouldn't be forgotten is fertilization. It's critical to maintain good plant vigor when dealing with diseases such as anthracnose, dollar spot and summer patch.

When planning a disease control program for greens, it's best to not extend any application longer than two weeks. Plant protection is limited by how long the fungicide can remain in or on the plant. The residual activity of fungicides is affected by many factors, including rainfall/irrigation, height of cut, frequency of cut and depth of roots. **GCI**

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Example of a fungicide spray program for *Poa annua*/bentgrass greens using a solutions approach to disease control

Diseases of bentgrass: Dollar spot (DS), anthracnose (A), Pythium blight (PB), brown patch (BP), yellow patch (YP), fusarium patch (FP)

Diseases of *Poa annua*: Dollar spot (DS), anthracnose (A), brown patch (BP), Pythium blight (PB), leaf spot (LS)

APPLICATION	TIMING	FUNGICIDE/PGR	RATE/1000 FT²	TARGET PATHOGEN
1	APRIL 1	BANNER MAXX DACONIL ULTREX PRIMO MAXX	2 FL OZ 3.2 OZ 0.125 FL OZ	A, LS, YP, FP
2	APRIL 15	BANNER MAXX DACONIL ULTREX PRIMO MAXX	1.0 FL OZ 1.8 OZ 0.125 FL OZ	A, LS
3	MAY 1	MEDALLION CHIPCO 26GT DACONIL ULTREX PRIMO MAXX	0.25 OZ 2 OZ 1.8 OZ 0.125 FL OZ	A, LS, YS, FP
4	MAY 15	HERITAGE BANNER MAXX PRIMO MAXX	0.4 OZ 1.0 OZ 0.125 FL OZ	A, DS, LS, SP
5	JUNE 1	CLEARY'S 3336 DACONIL ULTREX PRIMO MAXX	4 OZ 3.2 OZ 0.125 FL OZ	A, DS, BP, LS
6	JUNE 15	HERITAGE MEDALLION DACONIL ULTREX PRIMO MAXX	0.4 OZ 0.25 OZ 1.8 OZ 0.125 FL OZ	A, DS, BP, SP, PB
7	JULY 1	BANNER MAXX SUBDUE MAXX DACONIL ULTREX PRIMO MAXX	1.0 FL OZ 3.2 OZ 1.0 FL OZ 0.125 FL OZ	A, DS, BP, PB
8	JULY 15	HERITAGE MEDALLION DACONIL ULTREX PRIMO MAXX	0.4 OZ 0.25 OZ 1.8 OZ 0.125 FL OZ	A, DS, BP, SP, PB
9	AUG. 1	BANNER MAXX DACONIL ULTREX SUBDUE MAXX PRIMO MAXX	1.0 FL OZ 3.2 OZ 1.0 FL OZ 0.125 FL OZ	A, DS, BP, PB
10	AUG. 15	BANNER MAXX MEDALLION DACONIL ULTREX PRIMO MAXX	1.0 FL OZ 0.25 OZ 1.8 OZ 0.125 FL OZ	A, DS, BP
11	SEPT. 1	CLEARY'S 3336 DACONIL ULTREX PRIMO MAXX	4 OZ 1.8 OZ 0.125 FL OZ	A, DS, BP
12	SEPT. 15	BANNER MAXX DACONIL ULTREX PRIMO MAXX	.5 FL OZ + 1.8 OZ 0.125 FL OZ	A, DS
13	OCT. 1	BANNER MAXX DACONIL ULTREX PRIMO MAXX	1.0 FL OZ 1.8 OZ 0.125 FL OZ	A, DS
14	NOV. 1	MEDALLION BANNER MAXX DACONIL ULTREX	0.5 OZ 2 FL OZ 5.1 OZ	A, YP, FP