Thru the Green

The Golf Course Superintendents Association of Northern California

DECEMBER 2020

Northern California Chapter GCSAA
Golf Course Superintendents Association of America

1ST ANNUAL TURF RESEARCH ISSUE

FEATURED IN THIS ISSUE

- *UC Riverside PoaCure ® Herbicide Report*
- *University of Tennessee: Turfgrass Management in the Shade*
- *Oregon State University: Golf Course Management During a Pandemic*

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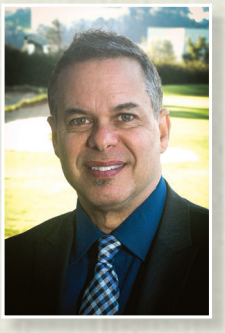

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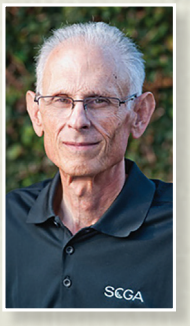

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COVER PHOTO: *Del Monte Golf Course, Home of 2020 GCSANC Excellence in Turfgrass (Public) Award Recipient, Vince Ferrante.*

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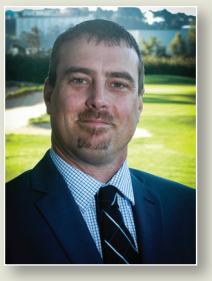

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Executive Director's Report

By **MARC CONNERLY**, *GCSANC Executive Director*

As indicated in earlier issues of Thru The Green, we have made a determined commitment this year to enhancing the look, feel and value of the magazine. Included in that commitment has been an effort to provide fresh, new content not previously found within these pages. For this issue, we are very pleased to present our readers with the first ever Turf Research Issue, something we intend to repeat annually.

After making the decision to put together an issue focused exclusively on research, we made a concerted effort to reach out to universities and researchers nationwide to pull together research studies from a variety of sources. The response could not have been more positive! In fact, we received so many articles that a few of them did not make it into this issue and will be included in upcoming issues of Thru The Green.

What is included in this edition is information obtained from UC Riverside and Cal Poly Pomona, plus Oregon State University, the University of Tennessee (several articles), and Mavis Consulting in Michigan. We have also included content from Jeff Jensen and Craig Kessler that is relevant to the theme of research.

Gratitude goes to Josh Lewis, Brian Boyer, GCSAA's Jeff Jensen, and Southern California's John Nachreiner (Shady Canyon Golf Club) and Jason Fuertes (Industry Hills Golf Club) for assistance in identifying and contacting potential research sources.

We hope you enjoy this issue and find the content informative and educational!

From the Field

By **JEFF JENSEN**, *GCSAA Field Staff, Southwest Region*

I hope this finds all of you enjoying some of California's beautiful fall weather. With this edition of the newsletter being focused on research, you are going to receive some great information from sources likeDr. Jim Baird, Oregon State University, the University of Tennessee, and others.

While we all recognize the importance agronomic research plays in the operations of golf facilities, GCSAA also offers some additional non-agronomic research to assist you with not only the operation of your course, but your career as well.

One of the most requested areas of non-agronomic research from our members is compensation and benefits. You may not be aware, but GCSAA conducts a survey and publishes the GCSAA Compensation and Benefits Report every two years.

The report is a great way to renegotiate your salary, assist with compensation information when interviewing for a new position or to help you determine proper pay scale and benefits for all members of your golf maintenance staff.

The report is not only broken down by state, but by metro area, facility demographic (private, public, 18-hole, 9-hole, maintenance budget, etc.) and chapter as well. Information for superintendents, assistants, equipment managers and crew positions are included. The last study was produced in 2019 and the next revision will be issued in 2021.

Did you know:

- The mean base salary (superintendents) of respondents in California was over $117,000 per year. For Class A superintendents it was over $121,000, and nearly $144,000 for Certified Golf Course Superintendents (CGCS).
- Of those surveyed, 98.5 percent of respondents (superintendents) in California indicated that their GCSAA annual dues were paid by their employer.
- The mean number of vacation days for a superintendent in California is 14.6.
- 95 percent of respondents (superintendents) are offered medical insurance and 88 percent dental.

While I could spout off numerous other facts and figures from the 123-page document, I encourage you to participate in the upcoming survey. The report is free to all survey respondents or can be purchased by those not participating for $125 at https://www.gcsaa.org/career/compensation-report.

Another terrific research document is the GCSAA Maintenance Budget Survey. The report is broken down by region (not state), facility type and average green fee, and assists superintendents in establishing baselines, trends and allocations of resources that they can communicate to their owners, general managers, management companies and green committees.

Southern California is located in the Southwest Region, with Northern California falling into the Pacific Region. Some of the line items included in the report are labor, water, fertilizer, fungicides, herbicides, insecticides, wetting agents, sand, seed, equipment rental, and fuel.

While budgets alone should never be used to compare courses, the averages by facility type, region and green fee can assist a superintendent in communicating budget decisions to other departments, as well as setting course expectations for their respective facility.

The maintenance budget survey is free of charge to all GCSAA members and can be downloaded at https://www.gcsaa.org/resources/research-information/operations-surveys-reports/secure/2018-maintenance-budget-survey.

Lastly, do not forgot about GCSAA's Golf Course Environmental Profiles. Used in part to help advocate for golf course professionals and the golf industry, the profile – articulated in reports and surveys – conveys accurate data on the land use, management of natural resources and environmental stewardship associated with golf courses across the country.

Five reports (Energy Use, Land Use Characteristics, Pest Management Practices, Nutrient Use and Management, Water Use and Conservation Practices) are included in Phase Two of the profiles, and they are a terrific tool for outreach to lawmakers, regulatory agencies, golfers, environmental groups, and media.

The reports are free of charge and can be downloaded at https://www.gcsaa.org/environment/golf-course-environmental-profile.

I hope these reports add some additional tools to your facility toolbox. If you have any questions or need any assistance in accessing them, please don't hesitate to contact me at jjensen@gcsaa.org, and thank you for your continued support of GCSAA.

Jeff

GCSAA
Grassroots Ambassadors

"The Ambassador program has broadened my horizons allowing me to experience an entirely different side of the industry many GCSAA members need to be more aware of. The decisions made by Congress are very important to the daily operations of golf facilities and getting involved in the process has been both eye opening and rewarding. "

Brandon Williams
Director of Agronomy
St. Mark Golf Club (CA-50)

CALIFORNIA CURRENTLY HAS MORE GRASSROOTS AMBASSADOR POSITIONS AVAILABLE THAN ANY OTHER STATE

Help us fill the remaining 20 positions before December 31, 2020

The open positions in California mean many of your representatives in Congress are not hearing from the golf industry. But you can help change this! Support and defend golf course management in California by becoming a Grassroots Ambassador today.

Ambassador Justin Mandon with Rep. Jimmy Pannetta

Ambassador Jim Ferrin, CGCS at California Golf Day in Sacramento, CA

Ambassador Mike Williams, GCSAA Southwest Region Representative Jensen with Rep. Pete Aguilar staffer

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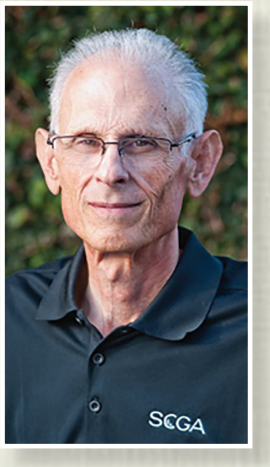

From the Bunker

By **CRAIG KESSLER**, *Director, Governmental Affairs, Southern California Golf Association*

THE SEARCH FOR RESEARCH DOLLARS

In many ways the golf industry is reminiscent of the trust fund baby born on 3rd base who goes through life thinking he or she hit a triple. Buoyed by two sources of subsidy, the game concluded that it grew to 30 million adherents by virtue of its genius – municipal governments that used taxpayer money to purchase, construct, and for decades operate the courses that introduced millions to the game at an affordable price point, and developers who built golf courses making zero business sense as stand-alone golf courses, but eminent sense as real estate loss leaders.

Golf never factored the role other sectors played in creating the supply for which it only needed to stimulate demand after the fact – and demand at subsidized price points no less. Throw in a post-World War II half century of unabated middle-class expansion, and you have what golf enjoyed for close to 60 years – steady growth and success.

But the music stopped at the turn of the Century. Municipal governments grew to not just expect, but demand net profits from their long-time net loss golf operations. The real estate industry extended their golf logic to their housing projects, yielding homeowners with inadequate resources to meet mortgages, and golf courses with no one willing or in many cases able to afford their price points and business models.

An interesting thesis you may say, but what the bleep does this have to do with research? The answer: Everything! No matter the subject, the game if it is to continue to thrive, let alone presume to grow, is going to have to stop waiting for others to invest in it and start figuring out ways to invest in itself. Research is not the only "investment" that fits this bill, but it's the one I'm going to focus on this month's screed "from the bunker." This is a Superintendents periodical after all.

When the industry sat down a few years ago to tackle its unmet needs, it landed on three high priority needs, one of which was research/education. The wise ones who sat down determined that an industry as dependent on reducing its water footprint and adopting politically and socially acceptable environmental practices as the California golf industry is not likely to achieve much of either without investing in the kind of pure research that is prevalent in those parts of the nation dotted with 19th Century Land Grant Colleges, but is almost indiscernible in the nation's largest state. One program at one UC campus almost totally funded by the golf industry, and no programs of any significance at the more hands-on state universities (the two Cal Polys) do not an effective turf research program make.

Yes, it's laudable that the SCGA donates $25,000.00 per year to turf research. It's much appreciated that the USGA has given a $250,000 grant to study the development of evergreen Bermuda grasses. The generosity of the GCSAA Chapters is impressive; they give more as a percentage of their budgets than anyone else. The CTLF does yeoman work with meager resources.

And for much of the history of the game in California these efforts were sufficient. They are no more. Continuing to pass the hat is akin to passing the buck. The problem is that there are no longer any takers. Golf either steps up to its own plate or steps aside and comes to terms with returning to its early days as a pastime restricted to the rich. By the way, whether the subject is taxes or golf, there is never enough "rich" to satisfy ambitions. Golf is going to have to do for golf. If it does not do what so many other California businesses routinely do, what so many business districts so routinely do, what so many business sectors routinely do, and what so many agricultural and other commissions do – assess itself in very small increments spread out over millions of transactions – it is destined to retreat to somewhere south of 14 million adherents. Not an appetizing prospect for those who work in the industry.

Those of you with sharp memories and sharper minds will recognize that I just described how the thousands of business improvement districts, agricultural commissions, and tourism bureaus operate in California. They understand that assessing oneself to raise monies to spend on oneself through collective means bears zero relation to a tax. A tax is something that you send to city hall, the state Capitol, or the national government with no control on how it is spent. A business or commission assessment is a direct investment in something for one's selfish benefit that to be meaningful can only be purchased collectively. A distinction with a powerful difference.

The industry started this discussion a few years ago. The discussion foundered on misinformation, miscommunication, and disinformation. But the unmet needs are still unmet. They are even more critical than they were when the discussion foundered, no need more than research/education.

It's time to sit down again. There is precious little time to waste. It won't be easy; things worth doing rarely are. But I have enough confidence in the industry's capacity for difficult things to believe that most of the game's institutions and leaders, albeit perhaps not all, are up to the task. We can always leave the unwilling out. Responsible leadership is never dissuaded by free riders.

Craig

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The Long and Winding Road of New Product Development

By **DEAN K MOSDELL, PH.D.**, *Western Technical Manager, Syngenta Professional Solutions*

The current price tag for a new agricultural active ingredient is approximately $300 million from identification of a new molecule that has merit for development to first market introduction. This road of product development can take over 12 years to complete, then add 1 to 2 years for California DPR review and approval. Thousands of compounds are evaluated each year to find the handful that may be screened and profiled on a larger scale, such as in greenhouses or field trials. With this price tag, the new products usually must fill a large gap or need in crop production in major markets, such as corn or soybeans.

Once a new molecule has been selected as a candidate for development, the big dollars are spent for registration. The next steps for development are the more than a hundred studies covering toxicology, metabolism, residues, ecotoxicology, physical-chemical properties and environmental impact. The crop protection industry is one of the most regulated in the world. The studies required for regulatory approval are performed to internationally agreed test guidelines. Data must meet the regulatory standards of the US and other major markets, such as Europe, Japan and Australia. Both field and laboratory trials must support safety for workers to use, and that it has no adverse effects on the environment, crops, or the food that will eventually be produced.

While the environmental, toxicology, residue, etc. trials are ongoing, the field efficacy (and safety) are conducted in countries where the initial markets have been identified. Within Syngenta, our turf and ornamental business has the opportunity to screen these new compounds in early development to find the best fit for the specialty markets. This allows us to include the turf and ornamental uses in the first registration submission of an active ingredient.

Discovery of new modes of action are difficult, but essential for the continued battle against resistance development. Even improvements in current chemistry are important sources of new products. Investigation for new products and modes of action include plant and microbial compounds, pharmaceutical libraries, patent investigations, and computer aided design.

The active ingredient in Divanem® nematicide was discovered on a golf course in Japan while screening for microbial extracts. Tenacity® herbicide was derived from bottlebrush plant exudates in Mountain View, CA, while Heritage® fungicide was developed from mushroom populations growing in a Czech Republic forest.

The most recent fungicides introductions are the succinate dehydrogenase inhibitors (SDHI) class. Although the first SDHI fungicide was introduced in the 60's, Carboxin, it's disease spectrum was narrow and only used in seed treatment. Product discovery companies understood the importance of this mode of action and began to optimize the molecule to improve disease spectrum. BASF introduced Boscalid in the early 2000s as an improved SDHI fungicide. However, disease spectrum was still limited, such as dollar spot only in turf. Syngenta got involved in SDHI research in the early 2000s using computer aided designs for unique compounds that are patentable and solve market needs for new products.

Syngenta has introduced 4 new SDHI fungicides for various markets, including 2 for turf uses. Adepidyn® fungicide is registered in California as a solo product, Posterity® fungicide, for powerful dollar spot, spring dead spot and fairy ring control. Also, in combination with Banner Maxx® II fungicide and Heritage® fungicide as Posterity® Forte fungicide and Posterity® XT fungicide for broad spectrum disease control. Posterity XT, not currently registered in CA, has a higher Banner Maxx II and Heritage content and less Adepidyn than Posterity Forte. Also awaiting registration in CA is Ascernity® fungicide and Contend® fungicide (a snow mold product combo). They contain SOLATENOL®, an SDHI, and difenoconazole, a DMI fungicide, that fit perfectly into a CA disease management program. Difenoconazole is a non-growth regulating DMI that's also found in the product Briskway® fungicide. Ascernity has excellent activity on anthracnose, brown ring patch, microdochium patch, large patch, as well as preventive activity on gray leaf spot and summer patch.

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The long and Winding Road of New Product Development

The path to new product development is long, winding and expensive, but critical to the production of food, fiber and the essential quality of life of turf and ornamental businesses. Syngenta continues to search for new products and new modes of action to provide the best tools for our customers.

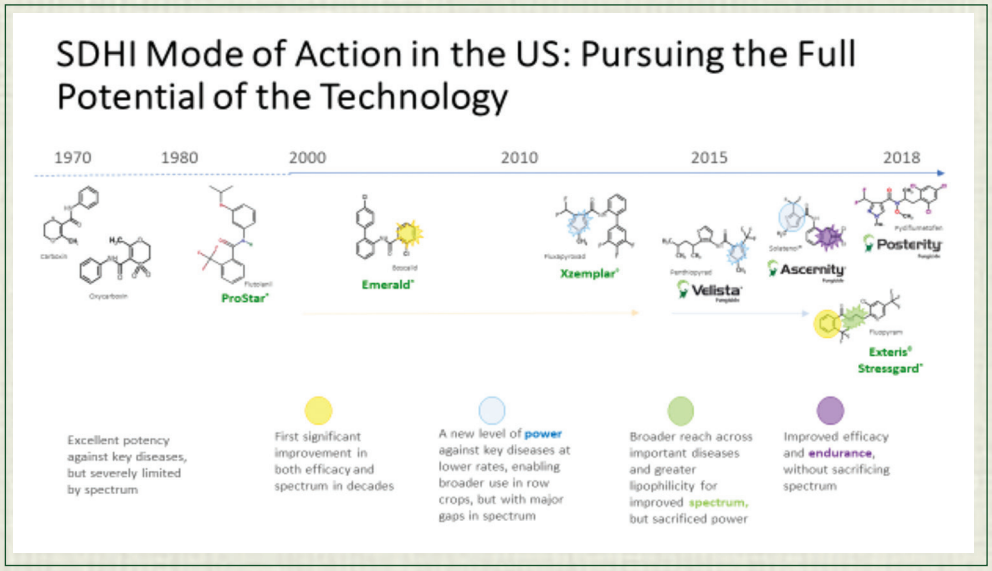

Figure 1. A brief history of SDHI chemistry. The carboxyl group includes SDHI mode of action, and was discovered for its powerful activity, mostly against one or two pathogens. Over time, with development of the chemistry, spectrums grew or changed, sometimes sacrificing power or longevity.

Golf Course Management During a Pandemic (COVID-19)

By **ALEC KOWALEWSKI, DOUGLAS SOLDAT, JAMES BROSNAN, AMBIKA CHANDRA, ROCH GAUSSOIN, BERND LEINAUER, FRANK ROSSI, JOHN STIER** *and* **BRYAN UNRUH**

INTRODUCTION

A novel coronavirus, termed COVID-19, spread worldwide and became a global pandemic in 2020. Forecasts show that COVID-19 will cause substantial economic contraction affecting almost every industry. Considering this, golf course superintendents, as well as other turfgrass industry professionals, are re-evaluating standard practices during a time of economic contraction. However, golf courses have several positive societal and environmental benefits. The maintenance practice and recreation use models on golf courses also facilitate social distancing.

At the onset of the COVID-19 pandemic, a team of turfgrass scientists from across the USA (Florida, Nebraska, Oregon, New Mexico, New York, Tennessee, Texas, and Wisconsin) worked together to outline the benefits of managed turfgrass on golf courses, as well as playing fields, recreational parks, and urban landscapes to assist decision makers with resource allocation in the COVID-19 era (Brosnan et al., 2020). This group of collaborating authors also worked to identify the minimum costs required to mow, fertilize, and irrigate turfgrass (Soldat et al., 2020). The following are the findings produced by these objectives.

BENEFITS OF GOLF COURSES

Environmental benefits of golf courses include flood control and groundwater recharge of filtered water when absorbing surface flows from residential areas. Biodiversity and abundance of wildlife and insects are maintained as many golf courses provide the minimum size necessary for multiple species, which is critical as populations decline globally.

Golf course rough and non-play areas make up 60–70% of most golf courses and often consist of conservatively managed grasses, trees, and shrubs. When combined with the open areas of fairways and greens, this greenspace creates viable wildlife habitat. Golf courses, like parks and forests, reduce the urban heat island effect. For instance, in Los Angeles, CA, temperatures on the golf course were 4 C cooler than the urban surroundings. In Colorado, well-managed golf courses fairways were found to have twice as much soil carbon, as the native prairie.

Golf courses can be built on reclaimed landfills, providing positive environmental and social benefits. Social benefits include the physical and mental health accrued through both playing the game of golf and the relaxation provided by being in nature, which has been shown to increase life expectancy.

Two-thirds of U.S. states deemed golf courses as "essential services" during the COVID-19 pandemic. Golf courses add ≥25% property value to homes depending on proximity. The golf industry nationally employs approximately 2million people, with an economic impact of nearly $180 billion. Golf courses consistently serve as fundraising venues, raising about $4 billion annually in the United States.

MINIMAL MOWING

Regular mowing during periods of active growth is a defining feature of natural turfgrass systems. Functional aspects of turfgrass systems (e.g., putting greens, tees and fariways), turfgrass species, cultural practices (e.g., irrigation and fertilization), climate, and soil type determine mowing requirements. Climate and soils being fixed, proper species selection and minimal cultural practices are the most effective means of reducing mowing requirements. Mowing more frequently results in a higher energy requirement, greater emissions, increased labor, and increased financial cost. Therefore, it behooves the turfgrass manager to establish standards (height of cut, frequency, performance, etc.) that balance functional needs with optimized growth rate.

The suggested mowing frequency and height for putting greens (annual bluegrass, creeping bentgrass and hybrid bermudagrass) during a period of economic contraction or low/no use is three times per week at 0.15", which will cost $33.5 per acre per month. The suggested mowing frequency and height for fairways, tees, approaches and surrounds during a

Continued

period of low/no use is twice a week at 0.5-0.75" (depending on the turfgrass genus and species), which will cost $10 per acre per month. The mowing frequency and height for roughs during a period of economic contraction is once a week at 1.5-4.0" (depending on the turfgrass genus and species), which will cost $10 per acre per year. It is important to note these mowing cost per acre calculations are based on federal minimum wage, current price of fossil fuel, manufacturer specifications and maximum mowing speed and do not include loss in productivity associated with turning and maneuvering or travel time to and from mowing locations.

MINIMAL FERTILIZATION

Crop yields are critical for understanding agricultural economics; however, yield maximization has never been a goal of turfgrass management. In fact, excessive yield results in increased management costs and suboptimal aesthetics as well as function. However, quantifying yield of turfgrass is important for estimating input costs. For example, nutrient needs can be estimated by multiplying the turfgrass dry matter yield by the tissue nutrient content, mowing requirements can be estimated by the rate of turfgrass growth, and irrigation needs are often correlated with turfgrass yield.

Turfgrass requires 16 essential elements to complete its life cycle, of which all but one [nitrogen (N)] are routinely found to be non–growth

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Golf Course Management During a Pandemic (COVID-19)

limiting. Although phosphorus (P) and potassium (K) are often routinely applied by turfgrass managers, these nutrients are typically found in levels well above growth-limiting thresholds. Therefore, during an economic crisis, maintenance applications of P and K can be withheld for a short period of time without negative consequences in a large majority of cases. However, most turfgrass is constantly in a state of N deficiency, and, if neglected, many problems can occur. Therefore, here we consider the minimum N input costs to managing turfgrass in an economic crisis or to otherwise maximize profitability without sacrificing aesthetic or performance goals.

Annual N needs and costs were conservatively calculating using the PACE Turf relative growth potential model (PACE Turf, 2014). The estimated annual N use for cool-season turfgrass is 5 lbs N per 1,000 sq ft annually, raining from 4.4 to 5.9 lbs N per 1,000 sq ft depending on location. The estimated annual N use for warm-season turfgrass is 4.5 lbs N per 1,000 sq ft annually, ranging from 2.7 lbs N per 1,000 sq ft annually in a transition zone climate to 10.3 lbs N per 1,000 sq ft annually in a warm-season climate. Nitrogen fertilizer in the form of urea or ammonium sulfate can be found from suppliers at a cost of approximately $0.5 per pound of N. Considering this the average annual cost per acre for fertilization is $146. In many cases, N fertilization rates (and costs) could be far less than these estimations. If replacement levels of P and K are added, these costs will no more than double because P and K are used in smaller quantities than N and per unit costs of the P and K fertilizers are similar to that of N.

MINIMAL IRRIGATIon COST

Sufficient water, either through rainfall or irrigation, is essential for the growth and survival of turfgrasses. Inadequate water allocations can have significant negative impacts on the aesthetics and health of turf areas and under extreme conditions can result in complete loss of stands. In arid and semi-arid regions of the United States, the rate of evapotranspiration generally exceeds precipitation, and golf courses require supplemental irrigation to ensure functionality. However, climate change, recurrent drought, and rapid urbanization have increased public demands for potable water, leaving fewer freshwater resources available for landscape irrigation. In fact, governing bodies have increasingly established restrictive irrigation guidelines and provided incentives to reduce turfgrass acreage.

The escalating cost of potable water limits its use, even when water is available for irrigation. In some locations (Vancouver, WA, and Portland, OR), golf courses do not pay for irrigation water because they have access to surface water or groundwater.

All golf courses have electricity costs associated with pumping water for irrigation. As expected, the golf course located in the arid Southwest (Albuquerque, NM) uses more water and pays considerably more for water than golf courses in other regions. Limiting irrigation water to reduce costs during the pandemic would not be possible without seriously damaging or destroying the turf cover. Irrigation costs (water and electricity for pumping) vary widely, with the least expensive region, the Pacific Northwest, requires 23 inches of irrigation per year costing roughly $300 per acre per year. The most expensive region, the Southwest, requires 44 inches per year costing $3,671 per acre per year.

CONCLUSION

The ecosystem services provided by golf courses are predicated on the sites receiving appropriate resources for management. In the absence of allocable resources, these golf courses will deteriorate, leading to concomitant reductions in aesthetics, function, and recreational quality. Turfgrass management encompasses a range of activities, including cultural practices (e.g., mowing, fertilization, irrigation, cultivation, and pest management), for establishing and sustaining sites at a desired level of quality.

Although budget reductions are a likely reality of the COVID-19 era, prioritization of expenditures is necessary, and essential minimums should focus on the three primary cultural practices: mowing, fertilization, and irrigation. Mowing is the most basic practice needed to provide desirable turfgrass. Second, turfgrasses, like all living organisms, require nutrition which primarily comes in the form of fertilizer. Third, all plants, including turfgrasses, require water to sustain life and irrigation resources should supplement natural rainfall.

In an era of COVID-19-related budget constraints, decision makers should work with superintendents to identify essential minimums to ensure that realistic expectations for golf courses are achieved while mitigating negative impacts on ecosystem services. For example, nonprioritized reductions in spending on golf course management will result in poor playing conditions, further resulting in potential revenue loss as golfers seek other venues. The cascading effect can lead to the demise of a golf course and resultant loss of valuable greenspace nestled into urban and suburban development. Unkept and neglected landscapes are associated with higher rates of crime. Neglect of golf courses or eliminating their inputs altogether, is not advisable.

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The Mechanics of Mowing

By **JOHN SOROCHAN, PH.D.** *and* **CORY YURISIC M.S.**, *University of Tennessee*

As turfgrass managers, we are all aware that mowing is necessary. Although it keeps our turfgrass in playable condition, it is actually considered to be one type of turf stress. Cleanly cut turfgrass will produce a more consistent playing surface, and result in a higher shoot density. However, mowers that produce a poor quality cut create turf that is not aesthetically appealing, and can be detrimental to the overall health of the plant.

As the demand for high performing putting greens has increased in the past few decades, several studies have been conducted to search for ways to increase quality of cut. In the past, frequency of clip has been a popular topic of research and discussion. Frequency of clip (FOC) is figured on reel mower speed, number of blades, and the reel's revolutions per minute (RPM), and is used to determine the distance between clips. It has been shown that adjustments in FOC can actually allow superintendents to mow greens at a higher height while maintaining consistent green speeds.

Mowing frequency has also been studied with the hopes of improving overall turfgrass quality on putting greens. In a two-year study conducted by Frank S. Rossi, Ph.D. at Cornell University, the effects on putting green performance of six different walk-behind greens mower types at various mowing frequencies were evaluated. Results from this study show that although there is very little difference between quality of turf and ball speed under varying mowing frequencies, double cutting more than twice per week can increase stress.

Keeping sharp blades and bedknives is one of the fundamental ways to maintain a clean, quality cut (8). Although the previously mentioned studies have looked at good ways to supplement well-maintained turf equipment, the question now is what else can be done? To address this, a recent study at the University of Tennessee and Michigan State University funded by Toro has examined the effects of behind center distance of reel cutting units.

Behind center distance (BCD) is a measurement of the distance from the shear point of the bedknife to the reel centerline (Figures 1 and 2). Some superintendents may be familiar with the terms "Attitude" or "Aggressiveness," which refers to the angle of the bedknife in relation to the turf's surface, but what many turf managers don't know is that the bedknife angle and BCD are related. In general, a more aggressive mower will have a more extreme bedknife angle, thus the BCD will be increased (Figure 1). On the other hand, a less aggressive mower will tend to have a flatter bedknife angle and therefore, the BCD will be decreased (Figure 2).

In order for turf managers to create these variations in aggressiveness, Toro has designed the new Dual Point

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Figure 1. This diagram represents an example of an aggressive cutting unit. The red arrow indicates a steep angle of clip. Notice the BCD distance is further back from the reel centerline.

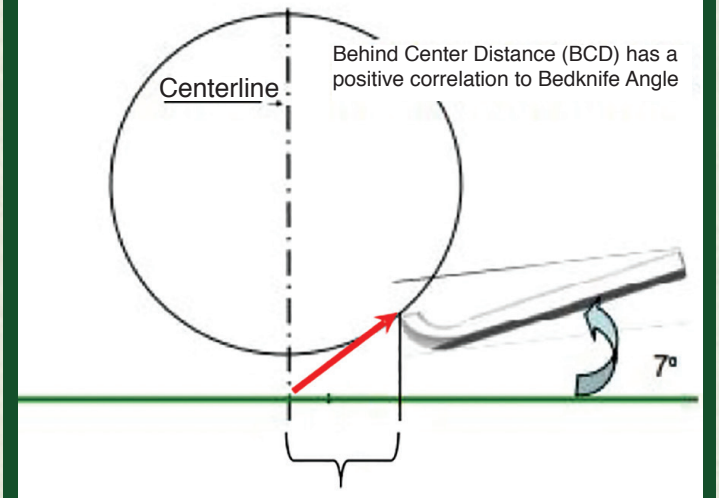
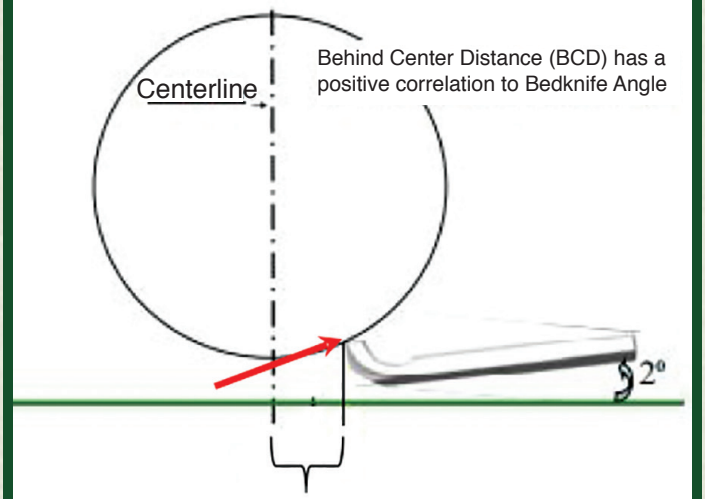


Figure 2. This diagram represents an example of a less aggressive cutting unit. The red arrow indicates a flatter angle of clip. Notice the BCD distance is now closer to the reel centerline.



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Adjustment (DPA) cutting units to be modified in several ways. First, a movable spacer on the rear roller mount can be positioned above (non-aggressive position) or below (aggressive position) the frame, causing the unit to roll either forward or back slightly (depending on specifications), which creates a change in the bedknife angle.

Second, an "aggressive" bedbar was designed, which allows the bedknife to attach at a steeper angle for use on aggressive setups. Last, either the Microcut bedknife or the Extended Microcut bedknife (offered by Toro) can be mounted on the bedbar to help further adjust the overall BCD setting.

In theory, a cutting unit with an aggressive setup is able to extend the edges of its blades further into the turf's canopy. This will result in the unit's ability to gather more turfgrass as it rotates toward the bedknife shear point. The fact that the reel blades are approaching the bedknife at an aggressive angle can potentially result in a more crisp and clean cut. Conversely, a less aggressive cutting unit is configured so that the blades approach the bedknife at a more horizontal direction, and will not gather the turfgrass as cleanly.

The long term benefits (or drawbacks) of using either an aggressive or non-aggressive mower were not fully understood prior to the BCD aggressiveness study, which is why the goal of the study was to determine what, if any, effects differing BCD settings had on the performance and quality of a putting green. Separate studies were run on three different species of turfgrass throughout the spring and summer of 2013 at the University of Tennessee and Michigan State University. Six BCD treatments were laid out in randomized complete block designs on a sand based 'V8' creeping bentgrass (Agrostis stolinifera) putting green, and a native soil 'TifEagle' ultradwarf bermudagrass (Cynodon dactylon x transvaalensis) putting green at the University of Tennessee's East Tennessee Research and Education Center. The study was also conducted on an annual bluegrass (Poa annua) putting green at Michigan State University. All plots were mown using Toro Greensmaster eflex 2100 tractors with floating head DPA cutting units.

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Table 1.

Treatment #	Bench HOC adjustment from control @ 0.125"	Adjusted Bench HOC	Actual BCD
#1	+ 0.015"	0.140"	0.385"
#2	+0.010"	0.135"	0.274"
#3	+0.005	0.130"	0.187"
#4 (control)	No adjustment	0.125"	0.164"
#5	-0.005	0.120"	0.082"
#6	-0.007	0.118"	-0.029" (FCD)*

Table 1 shows the actual BCD for each treatment based on the adjustment in bench HOC required to achieve an effective HOC of 0.125" for each cutting unit. All plots were mowed using Toro DPA cutting units attached to Toro Greensmaster eflex 2100 tractors. Treatment #4 is considered to be a standard BCD setup for greens, and required no change in bench height setting to produce an effective HOC of 0.125". Treatments 1,2, and 3 were considered to be more aggressive and heights were raised as necessary. Treatments 5 and 6 were considered less aggressive and their heights were lowered as necessary.

* Note that treatment 6 has a negative BCD value which indicates that the shear point actually precedes the center-line, and was thus given the designation, "Forward Center Distance" (FCD).

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There can sometimes be inconsistencies between bench height of cut (what height you set the reel to using the height gauge) and effective height of cut (what height the grass is actually being cut at). There are several factors that can create these discrepancies, one being the BCD setting of the cutting unit. Before initiating the trial, all six cutting units were set to a consistent effective height of cut (HOC) of 0.125". To do this, the control unit (BCD .164 @ 0.125" bench HOC) was used to mow the entire green area first. Then, the other five unit's effective HOC were checked against the control unit's height by making a perpendicular pass to the direction of the control. Differences in effective HOC were then compared visually using a prism gauge, and adjustments were made to the bench HOC of each treatment accordingly.

It should be noted that changes in height are inversely related to the reel's BCD. It is estimated that an increase in mowing height (on the front roller) will decrease the BCD by half the height change, whereas a decrease in mowing height will increase the BCD by the same ratio. The treatments with their adjusted bench settings can be seen in Table 1.

Parameters for this study included ball speed using a USGA stimpmeter, volumetric water content (VWC), clipping collection, and topdressing sand collection. Ball speed was measured using the USGA stimpmeter, taking the average total distance of three ball rolls in a forward and back direction. The average of the two directions was then calculated to figure out the total speed for each plot. VWC in the top 3" of root zone was determined using the Field Scout TDR 300 moisture meter by taking the average reading of three separate locations per plot. Clipping analysis was accomplished by collecting clippings from each individual plot from the mower buckets. Clippings were placed in the drying oven for 48 hours at 72 C, and the dry weight was recorded. Topdressing sand collected in the mower buckets after mowing each plot, was placed in an ashing oven for 48 hours at 525 C to burn away grass clippings and other organic materials, and then weighed.

Plots were also visually monitored for disease instances, as well as for the presence of moss at the M.S.U. location. Plots at the U.T. location were sprayed with fungicides on a preventative basis to avoid extensive turf losses during the summer months. Foliar nitrogen at a rate of 0.125 lb. Nitrogen per 1,000 ft^2 as well as Trinexepac-ethyl at a rate of 0.125 fl. oz. per 1,000 ft2 were applied to all plots on a biweekly schedule. Sand topdressing was applied to all plots at a rate of 85 kg per 1,000ft^2 every two weeks with USGA spec sand. Sand collections were taken the day following topdressing after the sand had been lightly dragged and irrigated into the canopy. Digital Image Analysis (DIA) data were taken on a weekly basis to detect differences in color (1-9 scale) and percent cover (0-100%). Digital images were imported to the Sigma Scan software program which analyzes the pixels and reports them as a percent cover and color rating (9). The U.T. location received above-average rainfall (~ 24") throughout the trial period; therefore, data collection and mowing dates were periodically either postponed or hastened until conditions became more ideal.

The following statistical data from the study were found to be analogous between each of the three turfgrass species. Therefore, for the sake of simplifying these data for a single report, results will be presented as a general overview for all three putting green species. Any statistical differences specific to a particular species will be noted throughout the rest of the discussion as necessary. Statistics were analyzed using ARM 7 statistical software. All data was run on an AOV means table, and was subject to analysis of variance using Bartlett's test for variance.

Ball speed was found to be statistically similar on 37 of 42 rating dates. On days when speeds were found to be different, volumetric water content was generally found to be high (35-40+% VWC). On these days, the green speeds were slow and varied between treatments. The effect on ball roll is believed to be the result of the highly saturated root zone conditions caused by the location's heavy rainfall rather than by the BCD. It should be noted that VWC was only significantly different on only two of the 42 rating dates. These differences varied between treatments on these two days, and are not likely related to a particular treatment.

No treatment differences were found for color or percent cover on the bentgrass green on eleven of eleven rating dates. Only DIA color differences were detected on two of ten rating dates on the bermudagrass green. Here again, these data are erratic in their variability among treatments, and these inconsistencies are more likely related to environmental conditions rather than BCD.

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California, Here Comes PoaCure® Herbicide – Are You Ready?

University of California, Riverside, Published October 2020 - **JIM BAIRD** *(Turfgrass Specialist),*
PAWEL PETELEWICZ *(Postdoctoral Scholar),* **PAWEL ORLINSKI** *(Junior Specialist)*

PoaCure® (methiozolin) herbicide from Moghu USA is currently registered in 46 states and the District of Columbia, not including Alaska and Hawaii (registration was not submitted), and not yet in New York and California. Although we're hopeful that California registration will happen sooner than later, many of you have been ready for PoaCure® for the better part of 10 years, which is how long UCR has been testing the product and how long we've been talking about it across the state.

Typically, experimental products from companies are not revealed to turf managers and even turf researchers as far in advance in the development process. However, PoaCure® is a game-changer, offering for the first time ever both selective pre- and postemergence control of annual bluegrass (Poa annua) in putting green turf. There's a good reason why so few herbicides are registered for greens and that is liability.

Herbicides target plants, and so even desired species can easily become the target when subjected to close mowing, intensive traffic, and biotic and abiotic stressors. So, as good as PoaCure® can be, it can also kill all of the turf on your putting greens if you don't follow directions for use and understand the general characteristics of the herbicide. As you've probably heard us say before about the UCR turfgrass research program, "Let us kill the grass, so you won't have to."

While Dr. Harold Walker from Auburn University and Dr. Shawn Askew from Virginia Tech University have the distinction of being the first in the U.S. to apply PoaCure® in the greenhouse and field, respectively, UCR has conducted more field and greenhouse research with PoaCure® than any other university in the world.

In addition to Riverside, a list of golf courses in California and surrounding states where UCR has conducted PoaCure® research is provided in Table 1. Even more golf courses in the state have tested PoaCure® either using a demonstration pack or under the Experimental Use Permit. The purpose of this article is to summarize our research findings so that your experience with PoaCure® in the near future will be well worth the wait.

TABLE 1.
Golf courses and facilities in California and surrounding states where UCR has conducted PoaCure® research during 2010-2020.

Golf Course	Location	Golf Course	Location
Anthem CC	Henderson, NV	Mayacama GC	Santa Rosa
Barona Creek GC	Lakeside	Monterey Peninsula CC	Pebble Beach
Bel-Air CC	Los Angeles	Morgan Creek GC	Roseville
Big Horn GC	Palm Desert	North Ridge CC	Fair Oaks
Brentwood CC	Los Angeles	The Olympic Club	San Francisco
The Bridges	Rancho Santa Fe	Peter Hay GC	Pebble Beach
California GC	San Francisco	Pleasanton Golf Center	Pleasanton
Callippe Preserve	Pleasanton	Poppy Hills GC	Pebble Beach
Cypress Point	Pebble Beach	Pronghorn Club	Bend, OR
Crosswater	Sunriver, OR	Sandpiper GC	Santa Barbara
Darkhorse GC	Auburn	San Francisco GC	San Francisco
Journey at Pechanga	Temecula	Shadow Creek	Las Vegas, NV
Lakeside GC	Burbank	Shady Canyon	Irvine
Las Vegas GC	Las Vegas, NV	Tehama	Carmel
Los Angeles CC	Los Angeles	TPC Harding Park	San Francisco
Martis Camp GC	Truckee	Toscana CC	Indian Wells

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California, Here Comes PoaCure Herbicide

RATES AND TIMING

PoaCure® is a sequentially applied, slow-acting herbicide. If all goes as planned, it will provide a seamless transition from a mixed stand containing Poa to a monostand of desired turf. In more situations than not, you're going to feel like the control is too slow or perhaps ineffective. In 10 years of researching this product on numerous golf courses, we've never met a Poa plant that didn't eventually die from PoaCure®. However, increasing herbicide rate or shortening frequency of applications is not the way to get the job done. Trust us, more often than not we've killed desired grass when adopting the "more is better" approach with this product.

The recommended rates of PoaCure® on putting greens and taller cut turf areas are 0.6 and 1.2 oz/1,000 ft2, respectively. Once again, you may think you can use higher rates on your particular golf course, and maybe you can get away with it some of the time, but we've already been there and done that to know that eventually it will come back and bite you. Thankfully for our golf course collaborators and us, the dead grass consisted of only a few small rectangles on a nursery or practice green. Overall, we're pretty sure that your golfers would rather have some Poa on their greens than completely dead grass on all of them.

Under normal circumstances, the frequency of PoaCure® applications is every two weeks. Later, we'll describe circumstances in which you may want to extend the period in between applications. While the pesticide label is the law and should be read and followed (see poacure.com for label and SDS), it is important to keep in mind that all pesticide labels are developed to a certain extent using a "one size fits all" approach for use instructions.

In the case of PoaCure®, up to six applications of 0.6 oz, totaling 3.6 oz/1,000 ft2, is usually sufficient to control Poa on greens in temperate climates with four true seasons. However, in most regions of California and the Southwest, the growing season is much longer and therefore we've found that a total of at least 4.8 oz/1,000 ft2 is often necessary for complete Poa control. So, this may result in a two- or multi-year span for achieving desired results with PoaCure®.

In cooler, coastal climates like Monterey and San Francisco, it is best to apply PoaCure® between May and October. Golf courses located in regions where summer temperatures often exceed 90F+ should apply this herbicide between November and June. Desert courses can follow the same schedule, except that applications may need to be halted earlier in the spring, as daytime temperatures rise consistently above 90F. Mountain courses with true winters and snowfall should apply PoaCure® between May and September.

"I THOUGHT YOU SAID POACURE® WAS SLOW ACTING?"

There are always exceptions when it comes to pesticides and their performance in various environments, and PoaCure® is no different. While it has been rare, certain Poa biotypes can be extremely sensitive to the herbicide, with complete death occurring after, for example, just 2-3 instead of 6-8 applications. We have also seen similar injury to or loss of certain creeping bentgrass segregates (e.g., Penn G-series) in older putting greens. If you sense this is happening, the best thing to do is lengthen the time period between applications and perhaps also use lower application rates.

We also know that intensive rainfall, or in higher elevations freezing temperatures and precipitation, can expedite PoaCure® activity much quicker than desired. Thus, it is important to adhere to application windows prescribed above.

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California, Here Comes PoaCure Herbicide

On the other hand, don't be surprised if you see other Poa biotypes looking rather unphased after several applications. Eventually, PoaCure® will eradicate the Poa. Will there come a time when Poa will develop resistance to PoaCure®? Judging by most other Poa herbicides, the answer is likely "yes." But, stay tuned in this article for more tips on using PoaCure® that will aid in resistance management.

TOLERANT AND SUSCEPTIBLE SPECIES

Golf course superintendents are probably most excited about using PoaCure® on creeping bentgrass putting greens. To date, there have been some anecdotal observations regarding relative tolerance or susceptibility among cultivars to this herbicide. We published a paper showing minimal differences in tolerance among creeping bentgrass cultivars tested, but on the other hand we clearly demonstrated that both velvet and colonial bentgrasses are very sensitive to PoaCure®. Since then, we have discovered that the creeping bentgrass cultivar 'Pure Distinction' is extremely tolerant to the herbicide, but we have yet to determine the exact reason(s) why.

One plausible but untested hypothesis is that Pure Distinction has a more robust root system that allows it to better tolerate the injurious effects of a root-active herbicide like PoaCure®.

Besides creeping bentgrass, PoaCure® is safe to use on most all major cool- and warm-season turfgrasses including bermudagrass on putting greens, seashore paspalum, and even kikuyugrass. However, it is important to note that applications on warm- (and cool-) season species should be avoided when the turf is dormant or semi-dormant and not actively growing. And while we are talking about this general subject, it should be mentioned that, in addition to annual bluegrass control (and seedhead suppression), PoaCure® can also be effective in postemergence control of rough bluegrass (Poa trivialis), and preemergence control of crabgrass, goosegrass, and certain broadleaf weeds.

KEYS TO SUCCESS

Besides following guidelines for rates, timing, and frequency of PoaCure® applications, watering in the product soon after application is paramount for success (we don't mean spinning the sprinklers one or two revolutions). PoaCure® is a root-active herbicide and thus it is very important to deliver the product to the root system. At least 0.1 inches, but better yet 0.2-0.25 inches, of water following application will help achieve this mission. Higher volumes of water are especially critical on taller cut turf for the herbicide to penetrate through the canopy and underlying organic matter layer. Natural precipitation can achieve the same objective if you have that much control over Mother Nature!

Speaking of Mother Nature, also know that excessive rainfall during the time of PoaCure® applications can expedite Poa control faster than desired. So, it is best to avoid applications during periods of extended wet weather. Our previous research has shown that higher sprayer carrier volumes equate to better Poa control, but even so it is still best to irrigate following application.

THINGS TO AVOID

It is worth repeating once again that PoaCure® is a root-active herbicide. Our research has shown that not only do Poa roots stop growing soon after application but also so do creeping bentgrass roots. So, presumably one reason for selectivity between tolerant and susceptible species is depth and volume of the root system. Creeping bentgrass root suppression from PoaCure® lasts about two weeks, which is the typical length of time in between applications. Therefore, it is important that the desired turf species has healthy and actively growing roots at the time of applications. Anything that can compromise the root system, including hot or cold weather, intense shade,

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intensive wear on perimeters of greens, or cultivation practices should be taken into consideration when applying PoaCure®.

If aeration, verticutting, or heavy topdressing and brushing are planned during the period of PoaCure® applications, it is best to allow at least 1-2 weeks between these practices and herbicide applications. Also, it is best to apply PoaCure® alone in the tank instead of mixing with other products just to be safe, and completely avoid use of Class B PGRs (flurprimidol and paclobutrazol) that are antagonistic to Poa and any other herbicides for at least 2-3 weeks before initial and final sequential applications of PoaCure®. This product is more than capable of handling Poa by itself. You need only be concerned about using products that will help creeping bentgrass or the desired species on which PoaCure® is being applied.

OTHER CONSIDERATIONS

One of the often-asked questions about PoaCure® is, "when can I interseed bentgrass into my greens?" Under most circumstances, PoaCure® applications will result in a slow, smooth transition of Poa from greens such that interseeding is not necessary. Obviously, the more Poa you have the longer it may take to complete transition. As a general rule of thumb, greens or turf areas with <20% Poa could be transitioned to 100% desired turf in 12 months or less whereas higher populations of Poa may dictate a two-year or longer transition period using lower rates or longer intervals between applications

If you feel you must interseed creeping bentgrass, it is best to wait at least 4-6 weeks after the most recent application of PoaCure® to avoid adverse effects on establishment. For those golf courses that overseed with perennial ryegrass, our research has shown that you must wait at least 10 weeks after seeding to avoid substantial injury to the ryegrass.

INTEGRATED POA MANAGEMENT

PoaCure® is one of the most revolutionary products to come along in our industry for selective Poa control in creeping bentgrass putting greens and other turf areas. However, once it is registered in California, relying on this product solely for Poa control is a guaranteed recipe for rapid development of herbicide resistance. Instead, PoaCure® should be used to clean up your greens or turf areas followed by implementing practices to prevent or minimize re-infestation, including: use of Class B PGRs like paclobutrazol and flurprimidol; hand removal; judicious irrigation management; and shade management, just to name a few. PoaCure® has both pre- and postemergence activity.

On greens and other turf areas that did not receive intensive traffic, ball marks, or divoting, we have seen residual Poa control for as long as two years after PoaCure® applications were ceased. However, Poa re-invasion could happen much sooner on higher traffic and wear areas where voids are created in turf. Coincidentally, for as long as we have waited for a product like PoaCure® to come along, we are now helping to develop cumyluron herbicide from Marubeni Corp. in Japan. Like PoaCure®, cumyluron has both pre- and postemergence activity on Poa in creeping bentgrass putting greens and other turf areas.

While PoaCure® possesses better postemergence activity, cumyluron excels as a preemergence herbicide with some postemergence activity that is most evident when initial Poa populations are <10%. U.S. registration of cumyluron is expected in 2022-23 and, together with PoaCure®, would greatly improve the battle against Poa and reduce or delay the chances of this species developing resistance to either herbicide.

SUMMARY

Good things come to those who wait, and thankfully for California golf courses, PoaCure® is on the way. When it arrives, patience with its use will be a virtue. Let PoaCure® do its job without hurrying its activity, and results will be well worth the wait.

Jim Baird can be reached at 951-333-9052 or jbaird@ucr.edu if you have questions or need assistance related to Poa herbicides or anything else.

Turfgrass Management in the Shade

By **JOHN SOROCHAN, PH.D.**, *Plant Sciences Department, University of Tennessee*

When it comes to managing turfgrass in shade, an understanding of the actual causes of shade is important. Shade is simply the lack of necessary light for optimal turfgrass growth. Reduced light, or shade, results in reduced photosynthesis, in turn causing the induced turfgrass stress. A simple definition for photosynthesis is light energy plus carbon dioxide plus water yielding chemical energy (carbohydrates) plus oxygen plus water. Light (sunlight) is the ultimate source of most terrestrial life on earth. The sun provides light in abundance and does not appear to be a limiting factor for most turfgrass growth. However, changes in light, either quantity or quality, has dramatic effects on plants, thereby making it a limiting resource.

The components of light include light quality and quantity. Light quality are the wavelengths of light (measured in nanometers, nm), and range from very short (cosmic or x-rays) to long (radio) wavelengths. Turfgrasses, like all plants, require visible light from 380 to 700 nm in order for photosynthesis to occur. This visible light spectrum (380 – 700 nm) is known as photosynthetically active radiation (PAR). Within PAR are the blue and red light wavelengths, which are important components for turfgrass growth and development. Blue light (≈ 380 – 500 nm) is important for photosynthesis, and is the stimulus for short, sturdy growth. Conversely red light (≈ 600 – 700 nm) is also important for photosynthesis, and is the stimulus for turfgrass cell elongation. Green light typically is not important for photosynthesis and is reflected giving the turf is green color.

Light quantity is the actual particles (photons) of light providing the energy necessary for photosynthesis to occur. Light quantity (energy) is the most important light component for photosynthesis to occur. The shorter the wavelength, the more energy provided; thus, blue light is more important for photosynthesis than red light.

Variations in light quantity occur with the time of year, latitude, time of day, atmospheric screening, and topography. During the summer, light quantity is greatest, while winter provides the least light energy. Depending on the time of year and latitude, the light quantity can vary greatly. In the northern hemisphere, the further north you go during summer, the longer the days are and greater the light quantity. Between 12:00 and 14:00, the light energy is most abundant and is significantly less during the time of day prior to and after the time when the sun is at it solar zenith.

Atmospheric screening reduces light quantity, and is caused by anything that has a potential to interfere with the light wavelengths. Clouds, pollution, humidity, and even trees are some examples of atmospheric screening that occurs. In addition to atmospheric screening, topography also influences light quantity. North versus south facing slope is an example of how topography can limit the turf's exposure to light energy.

Dr. James Beard estimated that over 25% of all managed turf is under some sort of shade stress. Thus, shade stress likely occurs anywhere turfgrass is managed, which can include golf courses, athletic fields, and home lawns, to name a few. Shade (reduced light) is a reduction in both light quantity and quality. Simply having a shade situation means not enough light energy is being supplied to the turf for efficient photosynthesis to occur. Reduced photosynthesis results in reduced carbohydrate synthesis, and in turn causes turfgrass stress conditions resulting in insufficient growth and development.

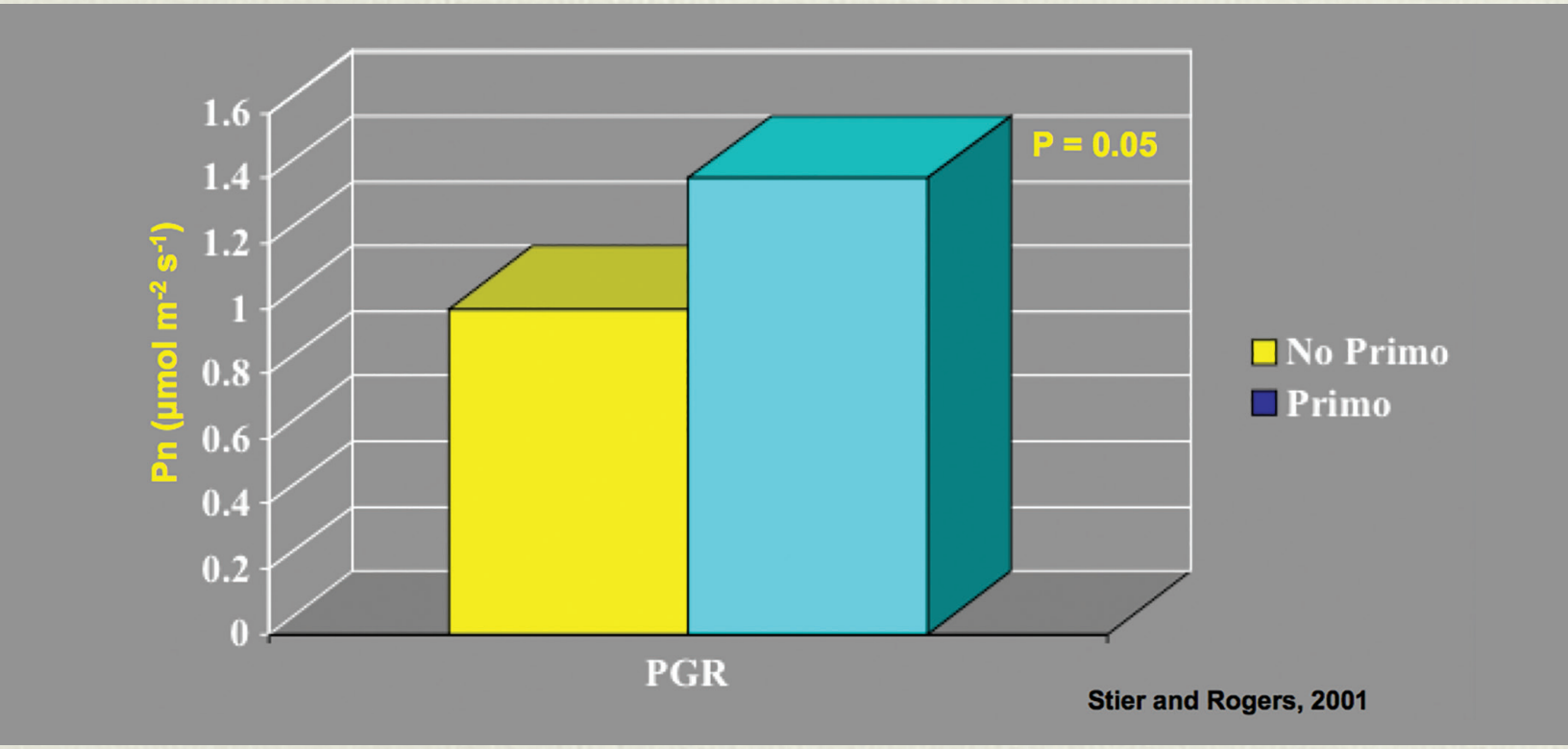
Tree shade greatly reduces both blue and red light quality, with the blue light being affected the greatest. As a result, the short, sturdy stimulus for turfgrass growth is reduced and turfgrasses elongate from the more abundant red light stimulus, and continue to lack the necessary light energy important for optimal photosynthesis to occur.

Morphological changes that occur as a result of shade stress include decreased leaf thickness, decreased density, decreased tillering (rhizome and/or stolon growth), decreased root to shoot ratio, and increased leaf height and elongation. Turfgrass physiological responses to shade include reduced carbohydrate reserves, reduced transpiration, reduced respiration, reduced cuticle thickness, and increased succulence.

Environmental conditions that typically accompany shade stress situations includes increased relative humidity, more moderated temperatures, restricted air movement, and potential competition for water and nutrients from tree roots.

Proper implementation of cultural practices can help when managing turfgrass grown under shade stress conditions. Because root depth is limited as a result of shade, a light and more frequent irrigation schedule should be used. However, avoid over watering! Irrigate only as needed to maintain adequate soil moisture for the turfgrass. Also, avoid excess nitrogen. Too much nitrogen will stimulate increased shoot growth, thus making the turfgrass plant more stressed.

Continued



A good rule of thumb to go by is to fertilize at half the recommended rate for nitrogen requirements for the turfgrass species being grown. If possible, increase mowing height to enable more surface area for light absorption. Unfortunately, for a shaded putting green increasing the mowing height is often not possible, because of the increased demands for faster putting surfaces.

Finally, turfgrasses under shade stress conditions have an increased susceptibility to fungal turfgrass diseases. Therefore, if possible, fungicide applications are often necessary for turfgrass survival.

Other management practices aiding in turfgrass shade stress situations include limiting or redirecting traffic, tree canopy and root pruning, plant growth regulators, and increasing morning light. Limiting traffic is difficult, particularly on putting greens. However, any reduction in wear will help alleviate added stresses to the turf already under shade stress conditions.

Trees are usually the major cause for shade problems, especially in golf course situations. Unfortunately, trees are also an important component to the golf course landscape. Trees add depth and aesthetic value to complement any golf course design. However, trees can also grow to exceed their original benefit and cause problems such as turfgrass shade stress. If the tree causing the shade cannot be removed, pruning both the limbs and roots will help reduce some of the problems being caused to the turf. Pruning the limbs will allow for more light to penetrate to the turf surface, and root pruning will lesson the competition for nutrients and water.

Several research studies have been conducted to show the benefits of using plant growth regulators (PGRs) on turf under shade stress conditions. The use of PGRs like Trinexapac Ethyl (Primo) have shown to limit shoot elongation and improve photosynthetic efficiency (Figure 1.).

Finally, when at all possible, any attempts to provide morning light will greatly help with dealing with shade stress conditions. Morning light is when cool-season photosynthesis is at its greatest, thus enabling for maximum photosynthetic efficiency.

X-Ray Vision? A New Approach to Studying Turfgrass Root Growth

By **JIM BROSNAN, PH.D** *&* **BRANDON HORVATH, PH.D**,
University of Tennessee **DAN MCDONALD,** *Phenotype Screening Corporation*
(This content was originally published in Tennessee Turfgrass, the official publication of the Tennessee Turfgrass Association)

Root growth is of interest to many in the turfgrass industry. Golf course superintendents, sports field managers and lawn care professionals all aim for healthy, high quality turfgrass with a robust root system and for good reason: roots not only allow turfgrasses to access moisture and nutrients from the soil, they also prevent erosion and confer surface stability. On a sports field, surface stability leads to better footing for athletes, and on a golf course it can lead to better traction and fewer divots. However, studying ways to improve turfgrass root growth has proven difficult.

Often, root growth is studied using core samples extracted using a golf course cup cutter or similar device. Root length is commonly measured using core samples and, in some cases, showcased on social media (Figure 1). In some instances, core samples are used to quantify root mass. The process of quantifying root mass involves: 1) washing the core to remove as much debris as possible; 2) drying the core and recording the weight; 3) placing the dry core in a furnace to remove all organic material; 4) weighing the resultant mineral material. The difference between the initial and final weight (i.e., what was essentially burned away in the furnace) is then reported as root mass. More in-depth experiments have washed cores free of soil, scanned clean roots into an image, and analyzed the image with different software platforms.

All of these techniques are limited by one thing—it's difficult (if not impossible) to take enough core samples from sites to detect a meaningful difference. For example, on an area basis, one golf course cup cutter samples 0.003% of a 3,000 ft2 putting green. In order to look at only 1% of that 3,000 ft2 putting green, one would need to extract over 300 cores. This destructive nature of extracting cores from a putting green renders this process impossible in most cases. Conclusions about root growth using an insufficient number of cores are essentially meaningless.

X-ray technology may offer a new means of studying turfgrass root growth without the need for extensive, destructive sampling. Researchers at Phenotype Screening Corporation (Knoxville, TN, http://www.phenotypescreening.com/) have patented a method of studying root growth in a manufactured rootzone with x-ray imaging. The process is fairly straightforward; plants are established in x-ray transparent containers packed with polystyrene beads similar in size to coarse sand (0.5-1.0 mm diameter) and supplied moisture and nutrients via fertigation. X-ray images are captured to make a clean, non-destructive, assessment of root growth. Polystyrene does not attenuate X-radiation and is therefore invisible in the image (Figure 2).

In 2020, researchers from the University of Tennessee and Phenotype Screening conducted a collaborative study to better understand the effect of a vermicompost organic liquid extract (WPT; Worm Power Turf, Aqua-Aid Solutions, Rocky Mount, NC) on annual bluegrass (Poa annua) root growth. Pre-germinated annual bluegrass seedlings were transplanted into polystyrene rootzone profiles inside a controlled environmental growth chamber configured to provide daytime and nighttime temperatures of 79-84°F and 61-72°F, respectively, under 14 hours of light. Rootzone profiles were supplied with a complete nutrient solution (i.e., Hoagland Solution) via a drip irrigation system.

After acclimation to this growing environment, plants were divided into two groups such that they received nutrient solution plus WPT (8.5%) or only nutrient solution. Treatments were arranged in a completely randomized design with six replications, each containing four sub-samples. All rootzone profiles were subjected to X-ray image analysis at 66 or 88 days after treatment (DAT). All images were analyzed using ImageJ software (Rueden et al. 2017) with assessments of projected root area, total root length, and root cross-sectional area (by depth in the profile) compared using standard error of the mean.

After image analysis, root tissues were dried in a forced air oven and weighed to quantify root mass. X-ray image technology revealed that WPT increased all measured root parameters compared to controls that only received nutrient solution. Interestingly, WPT treatment increased root cross-sectional area throughout the top six inches of the rootzone profile (Figure 3), which is of particular interest to those managing turfgrass on putting greens.

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A New Approach to Studying Turfgrass Root Growth

This research is just one example of the potential for X-ray technology to aid in furthering understanding of turfgrass root growth. Future research could be conducted to better understand root growth of other turfgrass species and cultivars in response to various crop protectants, as well as responses to various abiotic stressors (e.g., heat, drought, etc).

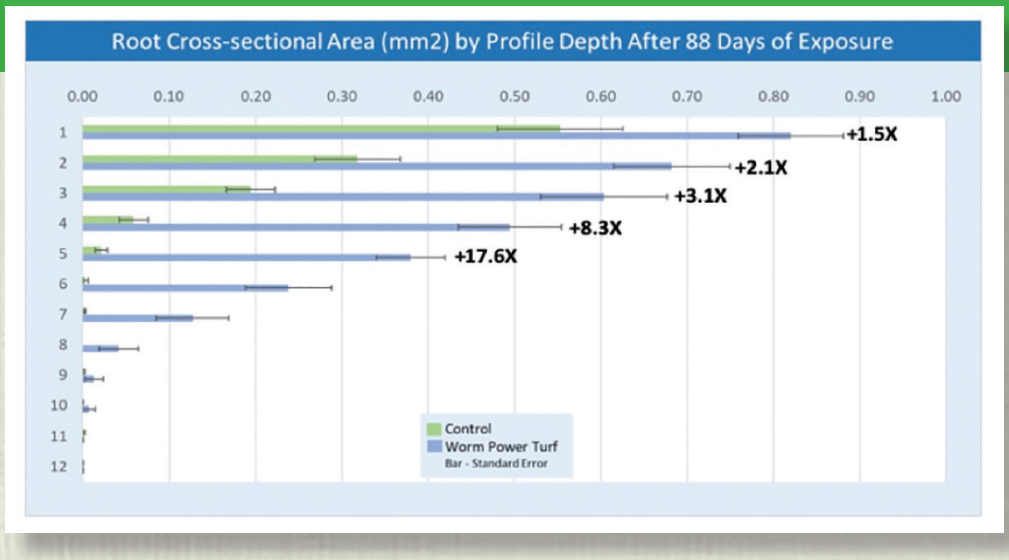
CITATIONS

Rueden, C. T.; Schindelin, J. & Hiner, M. C. Et al. (2017), "ImageJ2: ImageJ for the next generation of scientific image data", BMC Bioinformatics 18:529, PMID 29187165, doi:10.1186/s12859-017-1934-z

Figure 1. Image of a core sample shared on social media to highlight turfgrass root growth.

Figure 2. X ray image of annual bluegrass (Poa annua) root growth

Figure 3. Annual bluegrass (Poa annua) root cross-sectional area (mm2) throughout the rootzone profile 88 days after treatment with a vermicompost organic liquid extract in 2020.



Alternative Weed Control in Turfgrass

By **D.E. CARROLL & J.T. BROSNAN**

(This content was originally published in Tennessee Turfgrass, the official publication of the Tennessee Turfgrass Association)

In certain regions of the United States and Canada, legislation has severely restricted traditional synthetic herbicide use in residential and commercial landscapes. Specifically, residential use of synthetic pesticides deemed "cosmetic use" in the Ontario Province, Canada, has been banned.

Other aspects of the turfgrass industry, such as sports and golf, are able to receive exemptions through government approval, stated reduction goals, integrated pest management certification, and increased transparency requiring reporting and in-person meetings to discuss pesticide application (Ontario Regulation, 2018).

Similarly, in Montgomery County, Maryland, the use of synthetic pesticides perceived for use cosmetically is banned. Only natural, non-synthetic herbicides listed by the Organic Materials Review Institute (OMRI) may be used for this purpose (County Council for Montgomery County, Maryland, 2019).

Many local governments, such as the city of New York, banned glyphosate use on public land such as school districts, parks and in municipalities, except for maintenance of invasive plants in native area (The New York City Council, 2019).

In the United States, many active ingredients in organic pesticides are considered minimum risk, categorized as section 25b products, and are exempt from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration process. Products must meet six criteria for inclusion in this category. Because labeling in this category is typically not federally regulated, labeling of non-synthetic herbicides is not consistent and may include wording such as "organic" or "natural," despite these products not undergoing typical organic product registration.

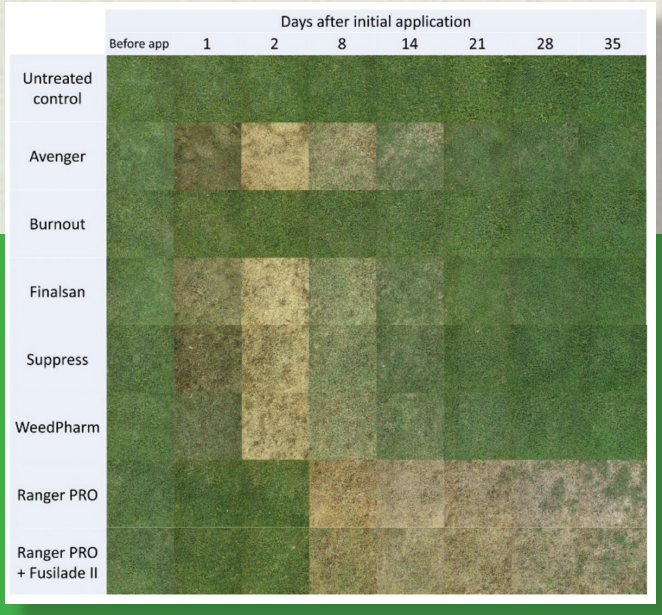
Although not required by federal law, independent agencies perform organic standard research to determine which products receive organic seals on labeling (Figure 1). Additionally, individual states may still require a registration process for minimum risk products and may limit herbicide use in some areas to only products listed by independent testing agencies.

An example of a natural product research agency that maintains a list of products compliant with internal organic standards is OMRI. OMRI is a non-profit organization, and thus not considered a regulatory agency. Conversely, the Environmental Protection Agency is considered a regulatory agency and although not federally required, also tests natural products and lists those meeting organic criteria.

Figure 1. *The Organic Materials Review Institute and Environmental Protection Agency seals of organic certification may be printed on herbicides meeting organic standards outlined by the organizations.*

Active ingredients on these lists include chelated iron, acetic acid, corn gluten meal, and a variety of soaps and oils. Chelated iron, also referred to as Iron HEDTA, is concentrated iron formulated for increased uptake in broadleaved weeds versus grasses. Once inside the plant, the iron is oxidized and causes necrosis (Charbonneau, 2010). Acetic acid, which is concentrated in household vinegar used for cooking at 5%, is generally concentrated in horticultural vinegar at 20 to 40%. Horticultural vinegar applications can kill weeds by removing the waxy cuticle found on leaves, thus drying out the plant. Citrus oil and soaps such as pelargonic acid or ammoniated fatty acid work in similar fashion by stripping the leaf cuticle to facilitate water loss. Unlike many synthetic herbicides, products with these active ingredients are generally fast acting and results may be observed within a few hours of application (Figure 2).

Figure 2.



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Alternative Weed Control in Turfgrass

Products containing these active ingredients are widely available to the public and can be purchased at most big box retail stores and online (Figure 3). Due to the lack of regulation in labeling, many manufacturers produce products of differing trade names that have similar active ingredients included at variable concentrations. For example, horticultural vinegar is available as Green Gobbler concentrated at 20, 30, or 40% acetic acid; Eco Garden Pro (8% acetic acid + 5% sodium chloride); or as WeedPharm (20% acetic acid) among others.

A common misconception is that products labeled as "organic" are non-toxic. This is false. Similar to synthetic pesticides, product labels contain the signal words caution, warning, or danger to alert applicators to toxicity. "Caution" labeling indicates the lowest level of toxicity to humans followed by "Warning" meaning moderately toxic and "Danger" denoting high toxicity. An example of organic herbicide toxicity labeling is horticultural vinegar labeled with a "Danger" distinction because the product is a strong irritant and needs to be used with care. It is critically important that end-users read and follow label instructions for both conventional and alternative herbicides before application.

Most of these alternative weed control products are non-selective and are therefore injurious to desirable turfgrass (Figure 2).

Figure 3. *Alternative weed control products purchased from big box retail stores and online.*

To mitigate injury concerns, these alternative options should be used to spot-treat individual weeds rather than being applied via broadcast sprays. Research conducted at the Pennsylvania State University (University Park, PA) assessed the efficacy of AXXE (40% ammonium nanonate), horticultural vinegar (30% acetic acid), Fiesta (26.2% Iron HEDTA), Avenger (70% d-limone citrus oil), and A.D.I.O.S. (11.9% sodium chloride) for control of dandelion (Taraxacum officinale G.H. Weber ex Wiggers) and white clover (Trifolium repens L.) in perennial ryegrass (Lolium perenne L.). Herbicide treatments were applied in late July with sequential applications made on two or four week intervals. Three applications of Fiesta applied at 25.2 fl oz/1,000 ft2 every four weeks controlled clover and dandelion within six days of initial application through mid-October. While not considered injurious to the turfgrass sward, increased iron uptake in the desired perennial ryegrass stand resulted in grey discoloration (Figure 4).

Figure 2. *Natural, non-synthetic herbicides including Avenger (70% d-limone citrus oil), Finalsan (22% ammonium soap of fatty acid), Suppress (47% caprylic acid + 37% capric acid), and WeedPharm (20% acetic acid) resulted in injury to bermudagrass (Cynodon spp.) within one day of application. Photo credit: Maggie Reiter, Ph.D., University of California cooperative extension advisor.*

Figure 4. *Grey discoloration of perennial ryegrass (Lolium perenne) three days after Fiesta applied at 25.2 fl oz/1,000 ft2.*

Other natural, non-synthetic herbicide treatments, including AXXE (15% v/v) and horticultural vinegar (50% v/v) provided some control of both weed populations compared to an untreated check, although both were injurious to turfgrass (Figure 5). Treatments of A.D.I.O.S. (50% v/v) or Avenger (14% v/v) did not control dandelion or clover and were not injurious to desired turfgrass.

Research conducted at the University of Tennessee (Knoxville, TN) in summer 2019 found similar results. A trial initiated in late July assessed the efficacy of eight alternative herbicides (Fiesta, Avenger, Burnout, horticultural vinegar, A.D.I.O.S., Biosafe, Natria, and WeedBeater Fe) for control of white clover. Two weeks after treatment, several alternative products controlled white clover similar to a single application of Trimec Classic (2,4-D, MCPP, and dicamba) at 3 pt/A; these alternative treatments included single applications of

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Alternate Weed Control in Turfgrass

Figure 5. *Turfgrass injury three days after application of horticultural vinegar applied at 50% v/v.*

Fiesta applied at 12.6, 25.2, or 50 fl oz/1,000 ft2; horticultural vinegar (30% acetic acid; 50% v/v); and Avenger (70% d-limone citrus oil; 20% v/v). The desired fine fescue (Festuca spp.) turfgrass stand was discolored following Fiesta treatment and injured by horticultural vinegar and Avenger. Treatments of Natria (3.7% ammoniated soap of fatty acid; 20% v/v), Biosafe (40% ammonium nanonate;15% v/v), WeedBeater Fe (1.5% Iron HEDTA; 100% v/v) and A.D.I.O.S (11.86% sodium chloride; 33% v/v) did not control white clover. Burnout (24% citric acid + 8% clove oil; 6% v/v) controlled clover ~ 50% compared to a non-treated check.

A second trial was conducted in February 2020 at the University of Tennessee to assess efficacy of alternative weed control products for control of winter annual broadleaf weeds in dormant bermudagrass (Cynodon spp.). Eleven days after treatment, Fiesta applied at 12.6, 25.2 or 50 fl oz/1,000 ft2; AXXE (15% v/v); horticultural vinegar (50% v/v); and Natria (20% v/v) controlled broadleaved weeds such as hairy bittercress (Cardamine hirsuta), henbit (Lamium amplexicaule), mouse-ear chickweed (Cerastium vulgatum), and corn speedwell (Veronica arvensis) ~ 50%. Thirty-three days after initial treatment, the end of the study, Fiesta applied at 25.2 or 50 fl oz/1,000 ft2 with a three-week sequential application controlled these broadleaf weeds 60 to 80%, similar to Roundup Pro at 16 fl oz /A and Cheetah Pro at 82 fl oz/A. At the end of the study, AXXE, horticultural vinegar, and Natria, treated sequentially three weeks after initial application, controlled these broadleaved weeds ~ 25%. The low control provided by these products at the end of the study compared to the 50% control observed 11 days after treatment indicates that sequential applications should be made every two weeks to obtain the greatest weed control.

Results of these research projects show that alternative weed control products can reduce weed populations compared to non-treated turfgrass, although outside of Fiesta, they are generally not as effective as traditional synthetic herbicides. Alternative products are not translocated throughout plant tissue, which often results in regrowth of treated weeds. Therefore, sequential applications will be required for sustained weed control, which can be costly. For example, an application of Fiesta at 50 fl oz/1,000 ft2 is approximately $25.40 per 1,000 ft2, compared to $0.76 per 1,000 ft2 for an application of 2,4-D + MCPP + dicamba at 4 pt/A.

Changing legislation in certain areas of the United States and Canada may put pressure on synthetic pesticide use in turfgrass. Homeowners and turfgrass managers should be aware that while natural herbicides may be an effective tool compared to not using any weed control product, they are not an equivalent replacement to synthetic herbicides.

In scenarios where alternative weed control products are required or preferred, they can be used to control select weed species via spot treatments applied sequentially. Products containing high concentrations of chelated iron, such as Fiesta, or acetic acid can be used for broadleaf control when applied as sequential spot treatments. However, these applications can cause undesirable injury or discoloration to turfgrass. More research is needed to better understand alternative methods of controlling weeds in maintained turfgrass. Investigations pertaining to effects of environmental or meteorological factors on efficacy of these products are warranted.

The authors would like to thank Dr. Frank Rossi, Associate Professor and Extension Turfgrass Specialist at Cornell University, and Vickie Wallace, University of Connecticut Extension Educator and Program Director of UConn's Sustainable Turf and Landscape Program, for their assistance in developing this article.

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PG Cultural Practices

By **BRIAN MAVIS**, *Mavis Consulting Ltd., Turf and Soil Specialist*
Brian is part of the Amplify Network; learn more at https://www.amplifytogether.com/

The responses from my cultural practice presentations starting in 2014 have been encouraging, to say the least. The continued comments from turf managers indicating their willingness to evaluate new practices/ technologies at their site is exactly the reason I started organizing the data and sharing. My intent is not to say that every facility has to utilize solid tine aeration and abandon core aeration, but to give confidence that alternative methods can be successful. Five years later, superintendents across the country continue to share their experiences with me about how they have improved their operation by implementing different cultural practices. The following article is an attempt to share updated information regarding these cool season turf management strategies.

The goal of any subsurface cultural program is to maintain or reduce soil organic matter (OM), silt/clay content and compaction to improve turf health and playability. There are many tools that help to accomplish this, but it is up to the turf manager to determine what practices are best suited for their site based on many factors (budget, labor, existing physical conditions, weather, turf varieties, demands on playability, etc.). Superintendents should utilize representative samples and data to evaluate current practices and better determine future needs.

First and foremost, solid tine aeration only on putting greens has not worked everywhere to prevent organic matter (OM) accumulation. The main reason for this seems to be limited annual surface area disruption that allows for sand incorporation (<15% per year). Another reason for increased OM levels has been due to higher annual Nitrogen applications (>4 lbs./ 1000 sq.ft.). The final reason for increased OM appears to be due to insufficient sand application prior to solid tine aeration. If there is not enough sand applied prior to punching, then the traffic from additional sand application can result in holes being partially closed before completely filled, as pictured on the right.

One of the most interesting things to me is the ingenuity of superintendents to incorporate sand into greens. Applying sand prior to solid tine has proven to be extremely effective, and the next step is to brush or blow the rest of the sand into the holes. Anything that can be done to minimize traffic on open holes is a step in the right direction. The use of brushes or a drag directly behind the aerator is another piece of this puzzle.

The averages for the upper root-zone in some of the highest maintained greens remain at approximately <1% Clay, 2-3% Silt, and 2.15% OM (360 LOI) utilizing USGA/A2LA accredited testing at Brookside Labs. These are results for samples with the turf removed (top 1/8"), and they are not the same as samples tested that include the turf like the newer 360/440 testing. The 360/440 method is being conducted to help determine what portion of the organic matter is humus.

The data listed for greens 2 and 18 is from the original course I worked with that implemented solid tine aeration only fifteen years ago. Unfortunately, the physical testing was not conducted from year one, but the data from this year continues to rank among the lowest in silt/clay and organic matter content and among the highest in playability. These are sand based greens seeded to L-93, which has shown to be a very aggressive organic matter producer. A combination of conventional and deep-tine solid tine aeration disrupting >20% of the surface annually has worked to achieve these results. Three inches

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PG Cultural Practices

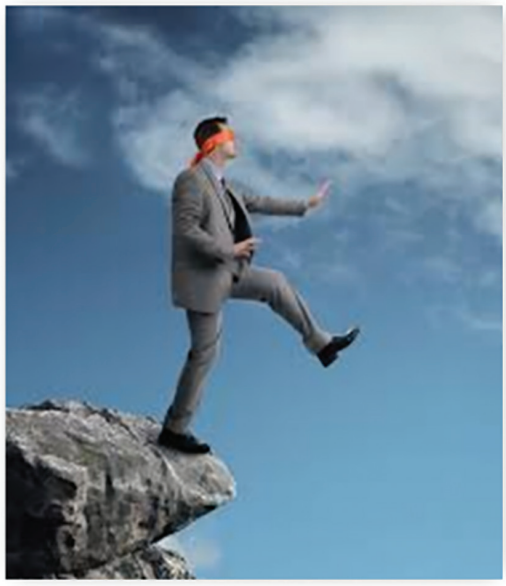
Date	Sample ID	Clay (%)	Silt (%)	Sand (%)	Organic Matter (%)	Fine Gravel - 2 mm (%)	Very Coarse Sand - 1 mm (%)	Coarse Sand - 0.5 mm (%)	Medium Sand - 0.25 mm (%)	Fine Sand - 0.15 mm (%)	Very Fine Sand - 0.106 mm (%)	Very Fine Sand - 0.0
	USGA Guide	*<=3*	*<=5*			*<=3*	*<=10*	*>=60*		*<=20*	*<=5*	
11/5/19	2G (0-2")	0.4	2.1	97	2.2	0.2	7.4	28.9	45.3	12.2	2.7	0.8
11/5/19	18G (0-2")	0.2	2.6	97	1.7	0.3	7.9	31.5	43.2	10.9	2.5	0.9
9/14/16	2-G (0-2")	0.8	2.3	96	2.4	0.7	6.4	30.1	41.5	12.9	3.9	1.4
9/14/16	18-G (0-2")	0.8	2.5	96	2	0.5	5.6	30.9	42.2	13.1	3.2	1.2
5/15/12	2-G (0-2")	0.4	2.8	97	2.5	0.3	4.2	33.1	44.3	11.5	2.4	1
5/15/12	18-G (0-2")	0.2	3.2	97	2.1	0.1	3.7	35.5	43.8	10.6	2.1	0.8

of sand has accumulated in the past 15 years on these greens, which equates 0.2" per year on average. Thank you to Matt Cielen for allowing me to share his data.

The cultural practices that seem to be most successful are those that disrupt 15-25% of the surface area each year that allow for sand incorporation. This can be a combination of solid tine, coring tines, vertical tillage (Graden, Sisis, VC-40, etc.), Dry-Ject to name a few. The availability of dry sand allows the vertical tillage to be effective as well as smaller coring or solid tines (0.3"). The smallest holes I have seen filled with wet sand were .375", but the ability to fill even smaller holes may allow for monthly aeration that has minimal effect on playability. If using 0.3" tines on 1.5" x 1.5" spacings, that would disrupt 3% of the surface area. Most that have been utilizing solid tines are using .625-.75" tines on 2" x 1.5-2" spacings to disrupt 7.6-11% of the surface each time.

Desired depth to aerate needs to be determined based on existing conditions (layers, compactions, etc.). Some situations need sand incorporated as deep as possible, while others may only need sand concentrated in the upper inch. There appears to be two new options for incorporating wet sand into the root-zone as well with a modification to Dry-Ject and now S-Tec Top Changer. The amount of surface area disrupted seems to be 5% or less for each machine, which suggests a need for additional aeration unless using these machines 3-5 times per year.

Whatever practices you are utilizing, I recommend monitoring the physical conditions with representative samples. Do not be the blind man heading towards the edge of the "cliff." Utilize the data to get out of your comfort zone and evaluate new practices for your site. Maybe you will stumble on the next practice or combination that helps improve turf management for everyone.



Water Conservation on Bermudagrass Fairways *(Cynodon dactylon x C. Transvaalensis)* in Golf Courses Using Soil Moisture Sensors and Multispectral Imaging Cameras

By Graduate Researchers: **BRIAN FUERTES, SEAN P. MCLAUGHLIN** *and* **MARK NAKATSUI**
Advisors: **PRITI SAXENA, PH.D** *and* **ALAN MOSS, MS**

To investigate the effectiveness of soil moisture sensor (SMS) technology by Toro (Turf Guard), Rain Bird (Integrated Sensor System) and Tucor on water conservation, research is being conducted on GN-1 hybrid bermudagrass at the Center for Turf, Irrigation, and Landscape Technology (CTILT) at Cal Poly Pomona University in California.

In 2020, the data collection will continue at CTILT for the second year. The experiment was designed as a complete randomized block on twelve GN-1 hybrid bermudagrass plots, maintained as fairways and replicated three times for each treatment and control. The analysis of water savings and turfgrass quality is continued to evaluate the efficacy of SMS-based irrigation system (treatment) in comparison to traditional evapotranspiration based (ET) irrigation practices (control).

Data collection includes weekly clipping yield, as well as visual turfgrass color, density, and quality ratings based on the National Turfgrass Evaluation Program (NTEP) rating scale. Overall water consumption of each treatment and control plot is monitored daily using Hunter HC flow meters. Real-time percent volumetric water content (%VWC) is monitored via SMS software to maintain a %VWC between field and capacity and wilting point.

ET rates are monitored from an on-site California Irrigation Management Information System (CIMIS) station and used to replace ET losses every two days. A multispectral imaging camera is then flown above the plots attached to an unmanned aerial vehicle (UAV) and captures images which measures light in a variety of spectral bands.

The primary goal of this research is to determine the potential effect that SMS and multispectral imaging technology may have on golf courses that are being impacted by water restrictions and/or prolonged drought and will assist superintendents to modify fairway irrigation scheduling and accurately quantify soil moisture and turf quality.

GCSANC Announces 2020 Annual Award Recipients

At its Virtual Annual Meeting in November, the Golf Course Superintendents Association of Northern California (GCSANC) announced the winners of the 2020 annual awards. We are pleased to recognize those individuals here. Watch for a comprehensive profile of each award winner in the next issue of Thru The Green.

Superintendent of the Year
JOSH CLEVENGER
Claremont Country Club

George Santana Distinguished Service Award
BOB KLINESTEKER
San Francisco Golf Club

Excellence in Turfgrass
(Private)
STEVE AGIN
Ruby Hill Golf Club

Excellence in Turfgrass
(Public)
VINCE FERRANTE
Del Monte Golf Course

Bert Graves Affiliate Merit
SUZANNE JOHNSON
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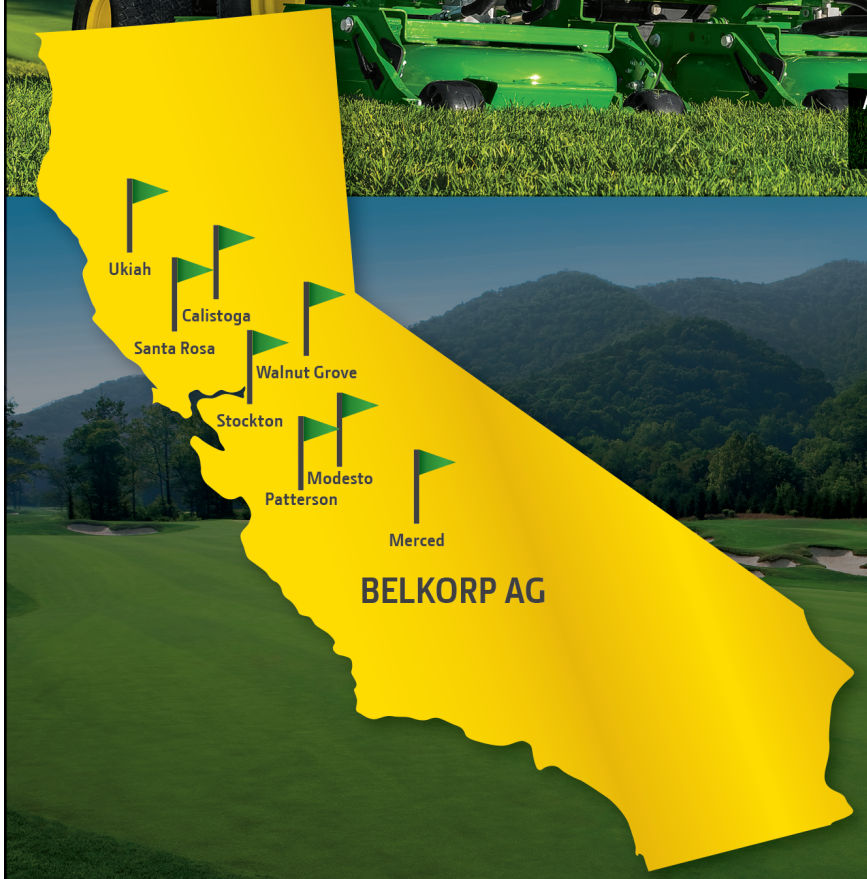

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