DRONES OFFER *UNIQUE PERSPECTIVE* TO TURFGRASS MANAGERS

New technology can bring a unique perspective to turf management. Unmanned aerial vehicles, or "drones," can provide valuable information to aid sports turf managers. As part of a management program, drones can save time, labor, and money.

Drones are semi-autonomous aircraft that come in a variety of shapes and sizes (see photo). Drones are capable of fully automated flight via GPS-based navigation or manual flight via radio-controlled transmission. They are available as multi-rotor helicopters and fixed-wing aircraft. Companies including Quadcopter, LLC, Lehmann Aviation, Pixobot, LLC, MicroPilot, Inc., and senseFly, Ltd. manufacture and sell drones for public use or provide drone-related services. They can be relatively small, about the size of a large pizza, to several feet in diameter or length. Drones require little technical training and do not require a pilot license for operation. They can operate in a wide range of environmental conditions. Drones can fly in hot or cold temperatures, humid or dry air, and sunny or cloudy skies. Although Federal Aviation Administration regulations currently prohibit drone flights for commercial operations, rule changes could come as early as 2015. Recently, farmers were granted permission to operate drones over their own property for personal use, in accordance with guidelines established by the Academy of Model Aeronautics.

▼ **A custom-made** unmanned aerial vehicle, or "drone," is shown flying over turf. Drones are used as a platform for digital image analysis, enabling quick and efficient quantification of turf quality and stress. *Image by Keenan L. Amundsen.*

WHAT DRONES DO

In a turf management program, drones are best used as a platform for collecting aerial imagery. Digital cameras collect visible light reflected from surfaces. Visible light is the portion of the electromagnetic spectrum "visible" to the human eye; it ranges from 400-700 nanometers (nm) in wavelength. Digital cameras record visible light information into three channels—red, blue, and green (RGB)—that make up each pixel in an image. Imagery can provide real-time information on many aspects of turf quality important to turf managers.

Images can be analyzed with computer software and used to quantify turf status through a process called digital image analysis (DIA). The DIA method is recognized for its ability

to objectively quantify many turf quality parameters, including percent green cover, turf color (via a dark green color index, or DGCI), fertility, chlorophyll index (i.e., "greenness"), and others. The objective nature eliminates variability associated with subjective visual ratings.

In addition to their impact on visible light reflectance, many turf stresses largely impact reflectance in the near-infrared (NIR) region of the electromagnetic spectrum. Near-infrared is the portion of radiation just beyond that visible to the human eye, ranging from 700-1300 nm in wavelength. The NIR provides the ability to "see" stressed areas otherwise invisible. Near-infrared radiation can be detected and recorded using a modified digital camera. Modification costs are relatively inexpensive, costing about the same price of a new mid-grade digital camera; pre-modified digital cameras are also commercially available.

Research at the University of Nebraska-Lincoln John Seaton Anderson (JSA) Research Facility near Mead, NE, in 2010-12 has shown RGB and NIR information in digital images can be extracted with computer software and used to quantify turf quality and stress. Two commonly used agronomic measurements include chlorophyll index (CI) and the normalized difference vegetation index (NDVI). Although computed somewhat differently, each is an objective measurement of turf "greenness," calculated by mathematical manipulations of red and NIR reflectance data. Other methods based on analogous principles involve handheld sensors. Handheld sensors are commercially available that measure visible and NIR reflectance from turf and quantify a value. Researchers have demonstrated high correlations among multiple turfgrass quality parameters with handheld CI and NDVI, making them robust, objective measurement tools. However, no attempts have been made to correlate these sensor data with a DIA system that incorporates NIR reflectance.

A dual-camera (regular + NIR) DIA system may be a convenient, reliable, low-cost alternative to handheld sensors for collecting turf quality data. Regular and NIR-modified digital cameras used in tandem can record RGB and NIR reflectance data for each image. These data could provide CI and NDVI information, as well as percent cover, DGCI, and traditional DIA measurements.

Furthermore, by combining DIA with drone technology, efficiency of collecting turf information increases dramatically. Drones provide the ability to image large areas, common in sports turf, in short time spans. For example, entire football fields can be imaged in minutes. By comparison, collecting imagery of equivalent area by hand would take several hours. Turf affected by various stresses, including water, fertility, disease, and insect damage, could easily be detected. In addition, because drones can collect information on entire areas in one image, effects of changing sunlight and cloud conditions are eliminated, increasing accuracy.

Research conducted at UNL in 2012 investigated effectiveness of a drone-based, dual-camera (regular + NIR) DIA system for measuring CI and NDVI compared to handheld sensors. An ongoing deficit irrigation field study established in 2009 was used. Deficit irrigation was applied via a linear gradient irrigation system, such that turf closest to the sprinkler line source received 80% evapotranspiration (well-watered) and turf farthest received no irrigation (rain-fed); plots were divided into eight equal sub-plots that differed in irrigation and replicated four times. This design provided a broad range of turf qualities for analysis. Plots were mowed twice weekly at 2.5 inches, fertilized at 3 lbs N·1000 ft-2·y-1, and received regular pre- and postemergence herbicide applications.

Aerial imagery was collected using a custom-built, GPS-controlled hexacopter equipped with a digital camera (Pixobot, LLC, Lincoln, NE). Aerial imagery of Bowie buffalograss (*Buchloe dactyloide*), 4-Season Kentucky bluegrass (*Poa pratensis*), Apple GL perennial ryegrass (*Lolium perenne*), and Spyder tall fescue (*Festuca arundinacea*) was collected on 6 days approximately every 4 weeks from early April through late September. Imagery was collected in full sun between 1200 and 1400 hr. The NIR imagery was collected immediately following regular image capture. A CI and NDVI were calculated for each image using the RGB and NIR data. The CI was calculated as (NIR / Red) – 1 and NDVI calculated as (NIR – Red)/(NIR + Red), based on equations developed by previous researchers. Traditional DGCI (which does not use NIR) values were also calculated for comparison against CI and NDVI.

Turfgrass	Handheld CI vs:		Handheld NDVI vs:	
	Drone-CI	Drone-DGCI	Drone-NDVI	Drone-DGCI
Buffalograss	0.78	0.75	0.71	0.71
Kentucky bluegrass	0.87	0.80	0.80	0.79
Perennial ryegrass	0.84	0.73	0.82	0.72
Tall fescue	0.87	0.74	0.82	0.75

▲ **Correlations** of handheld chlorophyll index (CI) and normalized difference vegetation index (NDVI) sensors among drone-based CI, -NDVI, and -dark green color index (DGCI). (n = 184 each; all results were statistically significant at the 0.001 level)

Chlorophyll index and NDVI data were also collected using handheld sensors. The CI and NDVI were measured using a Spectrum Technologies FieldScout CM 1000 chlorophyll meter and FieldScout TCM 500 NDVI turf color meter, respectively. Scores were averages of three random measurements taken in the center of each plot. Handheld sensor data were collected the same days as aerial imagery.

Our results showed strong correlations between drone-based CI and NDVI and handheld sensor data (Table 1). On average, drone-based CI data were highly correlated ($R \approx 0.84$) with handheld CI values across turfgrasses. Similarly, drone-based NDVI values were highly correlated ($R \approx 0.79$) with handheld NDVI values across turfgrasses. The

Future implications of drones in sports turf management are ongoing. Drones could be programmed to take off, fly routine routes, and land at specified time intervals, providing automated turf data over time.

drone-CI and -NDVI values were better correlated with handheld sensors than DGCI in all but one case.

These results suggest drone-based imaging using regular and NIR-modified digital cameras can provide information equivalent to handheld sensors. This allows CI and NDVI data to be collected in a fraction of the time required for handheld collection. Though our study used water-stressed turf, many other stresses and cultural practices have been correlated with handheld CI and NDVI, suggesting other stresses can be equally detected with drone-based DIA. These results also show addition of an NIR component to DIA increases ability to measure "greenness," illustrated by the stronger correlations with handheld CI and NDVI sensors than DGCI, which does not use NIR data.

MONITORING CHANGES OVER TIME

Drones can provide additional information valuable to sports turf managers. By using drones, changes in turf can easily be monitored over time. Furthermore, using drones to create GPS-based maps can easily pinpoint areas of turf stress. This information can then be used by sports turf managers to address the problem, whether it is increasing an irrigation zone run time to alleviate localized drought stress or increasing nitrogen fertility to correct chlorotic turf. With DIA, it is possible to model and calculate corrective measures (i.e., nitrogen rate must be increased by 0.20 lbs N·1000 ft-2 to alleviate turf chlorosis) with little error and simple mathematics, minimizing waste.

Future implications of drones in sports turf management are ongoing. Drones could be programmed to take off, fly routine routes, and land at specified time intervals, providing automated turf data over time. Drones could automatically detect turf problem areas with onboard software and generate GPS-based maps on the fly. If networked wirelessly to irrigation controllers, drones could trigger site-specific irrigation events to correct for localized dry spots detected during flight in real time. Drones also can be used to gather information other than imagery. Thermal-infrared imaging or infrared thermometers can measure turf canopy temperatures, which can indicate water stress. At UNL, preliminary work has begun on engineering drones for weed-control technology. The goal is to program drones to automatically seek, detect, and spray weeds with onboard herbicides.

By providing a birds-eye view of turf, drones can quickly and efficiency gather useful information regarding turf status that can aid in management. Through DIA, drones can provide quantitative information about turf in a timely and efficient manner. Turf parameters such as "greenness" (via CI and NDVI), color, percent green cover, and various stresses can be detected quickly and easily. The information from drones can lead to better-informed decisions. Thus, drones offer many advantages to sports turf managers that ultimately save time, reduce labor, and lower costs. ■

Scott M. Dworak is a PhD candidate, University of Nebraska-Lincoln Adjunct faculty, Biology Department, Doane College; Dr. Roch E. Gaussoin is head of the Department of Agronomy & Horticulture and Professor of Turfgrass Science, University of Nebraska-Lincoln; and Vishal Singh is with Pixobot, LLC.

Make use of preemergence herbicides this spring

Summer annual weeds such as crabgrass and goosegrass commonly invade athletic field turf. The stress of foot traffic from athletic competition can leave athletic field turf susceptible to annual weed invasion (Figure 1). Crabgrass and goosegrass complete their life cycle in one year, germinating from seed in spring, growing throughout summer, and setting seed in fall. Summer annual weeds invading athletic fields need to be controlled in order to maximize field quality and safety.

An effective means for controlling summer annual weeds is the use of preemergence (PRE) herbicides in spring. A list of preemergence herbicides labeled for use on warm- and cool-season turfgrasses commonly found on athletic fields is presented in **Table 1**.

Weed control programs centered on the use of PRE herbicides offer many benefits to athletic field managers compared to eradicating these weeds with postemergence (POST) herbicides after they become established. For example:

- Athletic field managers have more herbicide options to control summer annual weeds PRE than POST.
- PRE programs are often more economical than POST programs that can require numerous sequential applications.
- Several PRE herbicides are available on fertilizer carriers allowing for granular applications to be made instead of liquid sprays.
- Likelihood for undesirable turf injury with PRE herbicides is low compared to applying POST products to remove established weeds such as crabgrass and goosegrass.

Active Ingredient	Trade Name†	Formulations‡,¶	Labeled Species
prodiamine	Barricade	FL, WG	Bermudagrass Seashore Paspalum Tall Fescue Kentucky Bluegrass Perennial Ryegrass
dithiopyr	Dimension	EW, WP	Bermudagrass Seashore Paspalum Tall Fescue Kentucky Bluegrass Perennial Ryegrass
prodiamine + sulfentrazone	Echelon	SC	Bermudagrass Seashore Paspalum Tall Fescue Kentucky Bluegrass Perennial Ryegrass
pendimethalin	Pendulum	FL, G, EC	Bermudagrass Seashore Paspalum Tall Fescue Kentucky Bluegrass Perennial Ryegrass
pendimethalin + dimethenamid-P	FreeHand	G	Bermudagrass Seashore Paspalum
oxadiazon	Ronstar	G, FL, WSP	Dormant Bermudagrass (FL, WSP only) Bermudagrass (G only) Seashore Paspalum (G only) Tall Fescue (G only) Kentucky Bluegrass (G only) Perennial Ryegrass (G only)
indaziflam	Specticle	WSP, FL, G	Bermudagrass

† Active ingredients may be available under multiple trade names. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Tennessee Institute of Agriculture. The omission of a particular trade name is not intended to reflect adversely, or to show bias against, any product or trade name not mentioned.

‡ FL = flowable; WG = water dispersible granular; EW = concentrated emulsion; WP = wettable powder; WSP = water soluble powder; SC = soluble concentrate; G = granular (not on fertilizer).

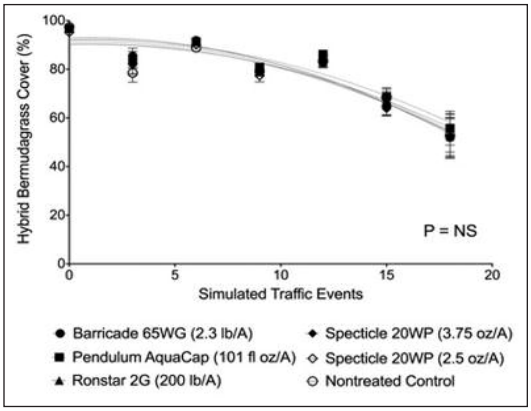
¶ Many preemergence herbicides are sold on granular fertilizer carriers. Be sure to follow label instructions to ensure that the correct rates of active ingredient and nutrients are supplied to turf when using these materials.

▲ **Table 1.** List of herbicide active ingredients labeled for preemergence (PRE) control of annual grassy weeds in warm- and cool-season turfgrasses commonly used on athletic fields.

THINGS TO REMEMBER WHEN USING PREs

#1- Application Timing: Be sure to apply PRE herbicides before weeds have emerged from soil (i.e., before they are visi-

ble). These herbicides do not prevent weed seed germination; rather they prevent germinated seedlings from developing into mature plants. Considering that the timeframe between weed seed germination and weed emergence can be quite short, it is often recommended that PRE herbicides be applied once soil temperatures are favorable for crabgrass seed germination. Athletic field managers should make their first PRE herbicide application as soon as soil temperatures (at approximately 2 inches) measure ≥ 55°F for a minimum of 3 days in spring.



▲ **Left: Figure 1.** Effect of simulated traffic on weed encroachment into hybrid bermudagrass in Knoxville, TN during 2013. **Right: Figure 2.** Effect of PRE herbicide treatments in spring on hybrid bermudagrass cover after being subjected to simulated traffic events in fall in Knoxville, TN in 2012 and 2013. Data were combined to present the effects of single and sequential application regimes at the rates tested in both years. Standard error bars presented as a means of statistical comparison.

Researchers studied how the blooming of 74 different ornamental plants in spring corresponded with the emergence of crabgrass in turf. They concluded that blooming of border forsythias is a helpful indicator of when to apply PRE herbicides for crabgrass control. Border forsythias produces distinctive yellow blooms at soil temperatures similar to those that facilitate crabgrass seed germination and emergence. Thus, athletic field managers should be sure to apply PRE herbicides before forsythia plants have completed flowering each spring.

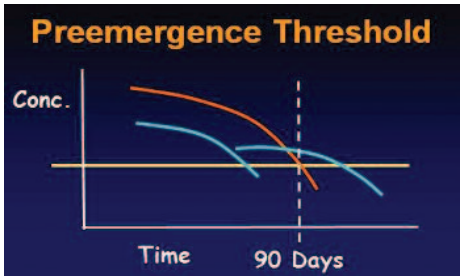
#2- Irrigation: A key to effectively controlling weeds with PRE herbicides is to water them into the soil after application. Most labels require that 0.25 to 0.50 inches of irrigation or rainfall be applied within 24 to 48 hours after application. These her-

Crabgrass plant's developmental stages

▲ **Forsythia** is in full bloom. The yellow petal drop has not started. *Photos and figure courtesy of Jeff Borger, Penn State*

▲ **Forsythia** yellow pedal drop has begun. About this time crabgrass will start to germinate.

▲ **Newly germinated** crabgrass in the spring of the year.



▲ **A visual** representation of the preemergence herbicide concentrations in the top ¼ inch of the soil profile following an application in the spring of the year.

bicides are absorbed by germinating weed seedlings in the soil, so moving them into the rootzone is critical. Failure to irrigate after application can also lead to material being lost due to volatilization. On fields without irrigation, try to time PRE herbicide applications around a period of rainfall.

#3- Split Applications: Split (also referred to as "sequential") application programs of PRE herbicides tend to provide more consistent control of summer annual weeds throughout a growing season, particularly in southern climates. These programs typically apply the total amount of active ingredient for the season in two equal rate applications spaced 8 to 10 weeks apart. A single herbicide application in spring for PRE control of crabgrass will slowly be broken down by soil microbial activity over the course of a summer often leading to crabgrass breakthrough by fall. Split application programs delivering active ingredient two times throughout a season tend to provide a longer period of control. Additionally, split application programs will control species germinating later in the year than crabgrass (e.g., goosegrass, etc.).

NO EFFECTS ON TRAFFIC TOLERANCE

Research has been conducted at the University of Tennessee Center for Athletic Field Safety (Knoxville, TN) evaluating the effects of four preemergence herbicides on Tifway hybrid bermudagrass traffic tolerance and recovery. Over the course of a 2-year study, no differences in smooth crabgrass control were detected among herbicide treatments after being subjected to athletic field traffic in spring; control measured 95 to 99% by 5 months after application. Additionally, these PRE herbicide applications for smooth crabgrass control had no effect on Tifway hybrid bermudagrass traffic tolerance to spring traffic.

Follow-up research at the University of Tennessee Center for Athletic Field Safety investigated the effects of PRE herbicide applications in spring on hybrid bermudagrass tolerance to traffic during the fall of the year. Similar to the initial study, PRE herbicide applications for summer annual weed control in spring had no effect on hybrid bermudagrass traffic tolerance in fall **(Figure 2).**

CONCLUSIONS

Numerous PRE herbicides are available for controlling annual grassy weeds on athletic fields. Always refer to the product label for specific information on proper use, tank-mixing compatibility and turfgrass tolerance. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Tennessee Institute of Agriculture. For more information on turfgrass weed control, visit the University of Tennessee's turfgrass weed science website at www.tennesseeturfgrass weeds.org.

J.T. Brosnan, G.K. Breeden, J.C. Sorochan, and A.W. Thoms
University of Tennessee

From high school to the big leagues: ZOYSIAGRASS FOR SPORTS TURF

▲ **Dan Bergstrom** of the Houston Astros in action last season. *Photo courtesy of Houston Astros.*

At Rangers Ballpark in Arlington, TX home of the Texas Rangers, Dennis Klein, Director of Major League Baseball grounds, says he "would recommend zoysia." For several seasons, even during Word Series Games, the Rangers infield was grassed with Zeon Zoysia, and then Y2 Zoysia, both developed by Bladerunner Farms in Poteet, TX.

"It did great," Klein says. "Zoysia is a little slower to establish than bermudagrass, and slower for the seams to lock together, but once it's in there and established it's really hard to hurt. We put it in in June and wouldn't replace a piece of grass on it until after the season. We went through a couple of World Series with it. The cutout at first and third base, and in front of the pitchers mound, you could beat balls into it and it wouldn't divot. It's really tough grass."

Klein says the Rangers installed the zoysiagrass infield at the request of the pitching coach. "We had been putting zoysia every year on the infield grass because we were able to maintain it at a taller height of cut to slow the ball down. The pitching coach wanted it tall and the zoysia of-installing the power cords runs across that hill. Concerts are a tough week for that hill and it stands up. We've been really happy with the zoysiagrass in that role," he says. "There was one time at a concert, a forklift fork was shoved into the hill and tore the grass. We replaced the divot and it healed back over the winter. I wouldn't expect to grow warm season grass in the winter but even some November damage healed."

▲ **Opening Night** at Minute Maid Park in Houston, March 31, 2013. *Photo courtesy of Houston Astros.*

fered varieties with more of an upright growing pattern, and a finer bladed type of turf that could handle the heat. That's why we went with it," Klein says.

This past season, the infield was grassed with 419 Tifway bermudagrass, at the request of the infielder players who wanted a shorter height of cut and a faster ball roll on the infield. "The infielders like it fast. The pitchers like it slow. This year we had a better earned run average with it fast as opposed to when I had it taller to help the pitcher," Klein says. "Sometimes coaches over-read these things. In my eyes, both teams have to play on it. You either have players or you don't have players."

▲ **The sloping,** grassed hill in centerfield at Minute Maid Park in Houston features L1F zoysiagrass. Photo courtesy of Houston Astros.

At Minute Maid Park, home of the Houston Astros, Dan Bergstrom, senior director of major league field operations, says "I'm really excited about the new zoysiagrasses."

Although the field at the park is mainly grassed in seashore paspalum, Bergstrom has tested Zorro Zoysia, Zeon Zoysia and L1F Zoysiagrass in certain areas. Right now, on Tal's Hill, the slope at the rear of the outfield that is in deep shade for most of August and September, Bergstrom maintains 2,500 square feet of L1F Zoysia.

"We put L1F on the hill and it has been absolutely gorgeous. It's got the esthetics we're looking for. We're able to mow it down tight under ¾-inch. It's a beautiful color. It's a *matrella* with a super fine texture. It's wear tolerant. It's been bulletproof," Bergstrom says.

Tal's Hill gets different, more aggressive wear than the rest of the field. "When a player makes a play on that hill, he gets there at full speed and stops at full speed, when he is chasing the ball to that hill. Every team that comes in does practice on the hill. The visiting center fielder will run up all over it for a half hour before batting practice," Bergstrom says.

"Our stadium tours go past the hill; it gets a lot of foot traffic. It's also the area immediately behind our stage for major concerts. All of our power cords, and all the traffic related to

WE'VE GOT YOU COVERED

EITHER WAY, YOU'LL WIN WITH TURFCO® SPORTSFIELD TOPDRESSERS

- Broadcast up to 40 feet for maximum productivity
- Patented WideSpin™ technology gives you the perfect spread with the least adjustments from light to heavy
- Spinner angle adjusts up and down for maximum versatility

- Just hook up and go—ground-drive system means no hydraulics or speed calibration
- 60" drop spreader with extra large hopper capacity for less reloading
- Patented Chevron® belt ensures uniform application of all types of materials, regardless of moisture content

TURFCO®

WWW.TURFCO.COM

Demo TURFCO on your field—call 800-679-8201 today.

TURFCO MANUFACTURING, INC. | 1655 101st Ave. NE | Minneapolis, MN 55449-4420 | TOLL FREE 800-679-8201

▲ **South San Antonio** High School's ball field grassed in Zeon Zoysia. *Photos courtesy of Richard Mendez.*

Zoysia has also been used on baseball fields at the high school level. Richard Mendez was the sports turf manager at South San Antonio High School in San Antonio when the field was renovated in October 2010. The original plan was to grass with bermudagrass but once he saw Zeon Zoysia, Mendez changed his mind. "It blew me away," Mendez says. "The feel of the grass, how when a ground ball is hit it slows the ball down because it is so thick, that was a good thing for our infielders, for the ball to slow down."

The base paths, infield, and outfield were all grassed with Zeon. Mendez says he noticed a difference in maintenance requirements almost immediately.

"I cut down my watering by 33%, if not more. This grass just needs less water," Mendez says. "I didn't have to run the sprinklers, especially during the tournament nights, so we didn't have to come to a wet field in the morning. For us it was a big plus, to be game ready a lot sooner for the morning game."

He also used less fertilizer on the zoysia than on the field when it was bermudagrass.

"We didn't have to fertilize but maybe a pound of nitrogen a year. That cut back our budget quite a bit. Our athletic director was pretty pleased about that, that we didn't have to buy as much fertilizer as we did with bermudagrass to keep it green," Mendez says.

He also no longer had to overseed the field.

"Maintenance costs were cut down in the fall and the spring because you didn't have to overseed anymore. The reason to overseed is to keep the body of the grass. Bermudagrass loses the body, zoysia does not. I wanted to paint it but we didn't. My test was that it would need to be green by the time our annual tournament came along in the second week of March. We had a green baseball field by then," he says.

Mendez says he sees a place for zoysia on sports fields.

"I think zoysia is going to be the grass of the future for sports fields because of the low cost of maintenance, especially in high schools, because school budgets are cut. If we can have less maintenance costs we can put that money into education," Mendez says.

Coach Donaldo Perez of Somerset High School in Somerset, TX guided his baseball team to the playoffs that were held at South San Antonio's field grassed with Zeon Zoysia. Perez says that both he and his players noted an improved difference on the zoysiagrass field.

"The grass at South San is so tight-knit. The ground balls to our players were so sound, a lot sounder than most fields. They were pure ground balls toward you. The field plays real smooth," Perez says. "The grass makes a difference in how the ball is played. I felt that that field really was a really good field to play on. We had some true hops. There are other fields that you play on that are not the same. This was really player friendly, ground ball friendly."

Charles Harris is president of Buy Sod, Inc., a licensed producer and installer of Zeon Zoysia in Pinehurst, NC and a member of the The Turfgrass Group's Zeon production network. Harris says he's grassed two high school baseball/softball fields with Zeon Zoysia in North Carolina so far.

"Zeon is very fine-bladed and esthetically, it's a great turf. The ball rolls across it very well. It's very dense," Harris says.

Using zoysia on the fields he's installed, he says, has produced "positive feedback. They've been very happy with the result of what we've put in."

Although zoysia is a very dense turf and can withstand a lot of wear, "once damaged, it doesn't have as quick a recovery as bermudagrass," Harris says.

Harris says the key is for sports turf managers to be aware that maintenance requirements on a zoysiagrass field are different than on a bermudagrass field. "I think it's just people getting used to growing zoysia. You can't grow it like a bermudagrass. It doesn't need the same amount of nitrogen feed. It's a little slower growing so the maintenance practices are different. It's a learning curve as they get into it," Harris says.

Although zoysia is a very dense turf and can withstand a lot of wear, "once damaged, it doesn't have as quick a recovery as bermudagrass," Harris says. "So the question is, how will it recover? What is the threshold for the number of events it can withstand? In many ways, it's better for maintenance and es-

thetics, but what we have to consider is, is it the right fit for the facility? I think it needs to be experimented with more and used more. It's certainly is a very good turf for sports turf. It could definitely work very well."

Kevin Morris is the Executive Director of the National Turfgrass Evaluation Program based in Beltsville, MD. Morris worked at NTEP for 15 years with the late Jack Murray, the legendary USDA turf breeder who is credited with bringing many of the zoysiagrass accessions from Southeast Asia into the United States, including, among others, the turf that eventually became Zeon Zoysia.

Morris says NTEP recently completed a 5-year trial on zoysiagrass and the program has plans to launch a new zoysia trial this summer that includes some 35 unique entries. So far, most of the testing NTEP has done on zoysia has been for home lawns and golf use. The program has yet to conduct a wear tolerance test specific to sports field use.

Still, Morris says, "zoysia holds a lot of promise." He notes that although there are real distinctions between cultivars, zoysia, in general "does have better winter hardiness than bermudagrass." The grass can also survive in lower pH soils. "The whole pH and low maintenance aspects are where it has advantages over bermudagrass or the cool season grasses," Morris says.

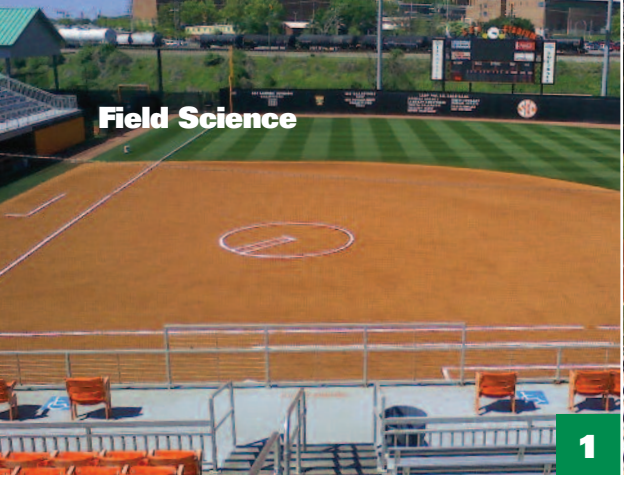
Brian Schwartz, Ph.D., is a zoysiagrass and bermudagrass breeder at the University of Georgia. "Zoysia has a stronger leaf … it doesn't wear a path as easily. It's a lower fertility input grass. So, from a benefit for the end user, they'll spend less on management and it maintains density. That's very important to an athletic field, that it maintains density with less input. If you fertilize bermudagrass with the same level of N, it would be alive but not as dense. I could see it working. That's why I think it would be a positive. There's better color retention into the fall. In the fall it doesn't change to the dormant color without a real freeze. Bermudagrass starts turning dormant, not only with cooler temps but with shorter day lengths. So, a lot of the zoysias need a freeze to turn them dormant. Some of them will be growing and recovering from a traffic event in the fall when there's football. So, that's a positive," Schwartz says.

"On the negative side, once the leaf in the canopy does get worn, it will have a harder time recovering as fast as bermudagrass," Schwartz says.

He says that he'd like to see more research on zoysiagrass for sports turf use. "I would love to see a football or soccer field grassed with 50 yards in zoysia and 50 yards in bermudagrass. That would be the coolest thing in the world for me. It would receive the same amount of wear and we would see which one would hold up. That's never going to happen, but it would answer 90% of our questions on one or two fields," Schwartz says.

"I just think there's a yearlong benefit of having zoysiagrass on a sports field like baseball or softball, where you're not worrying about wearing it out. For lower yearlong nitrogen rates, and less yearlong watering, you can keep the density so high and uniform with less inputs. Especially on a municipal level where you may ignore a field for a period of time, zoysiagrass could be ignored and you could get it back very quickly. At the lower input level, it could be very successful and beneficial for folks who can't keep up with the mowing rates and nitrogen rates that a high end bermudagrass would need," Schwartz says. "Add in some shade issues with stadiums, you have a fit for zoysiagrass for a lower requirement for light. Zeon would make a beautiful fit for stadiums because of shade." ■

Stacie Zinn Roberts is an award-winning writer and president of What's Your Avocado?, a writing and marketing firm based in Mount Vernon, WA



▲ **Field #1:** Sherri Parker Lee Stadium on the campus of the University of Tennessee, Knoxville. *Photo courtesy of Darren Seybold.* ▲ **Field #2:** Husky Softball Stadium on the campus of the University of Washington in Seattle. *Photo courtesy of Tyler Clay.*

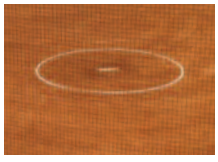
Advice on maintaining softball infield skins

SportsTurf asked the following turf managers who maintain softball diamonds a few questions on how they make their skins better.

- Tyler Clay, University of Washington
- Herb Combs, CSFM, Athletic Field Supervisor, Intercollegiate Athletics, The Pennsylvania State University
- Jason DeMink, CSFM, University of Michigan
- Eric Harshman, Assistant Sports Turf Manager, University of Kentucky
- Tracy Schneweis, Sports Turf Manager, America Softball Association Hall of Fame Complex
- Darren Seybold, Director of Athletic Surfaces, University of Tennessee

What combination of clay products, amendments, moisture and maintenance routine do you use to keep the pitcher's circle in top condition?

Seybold: The infield consists of a high density red clay material that helps us produce a firm but not hard surface that can absorb a lot of water but not lose its ability to produce a quality footing, as well as smooth ball/surface interaction. Our team in the past has been built around the concept of speed and therefore the coaching staff wanted a "hard" surface. This material allows the agronomy staff to have enough water in the profile to provide the infielders with a tremendous fielding surface as well as accommodating the teams need to have a fast surface for their hitters to slap hit and steal bases.



Leaving your finished clay work a fraction of an inch below the rubber will promote less digging, and limit the opportunity for the surrounding surfaces to build-up. —*Tyler Clay*

DeMink: We patch daily and apply conditioner as needed. The only amendment we use is a natural clay enhanced with polymer.

Combs: We use mound clay for our pitching mound and cover it with a thin layer of amendment. The mound is repaired daily and watered as needed. To help maintain the overall quality and moisture of the mound we tarp when it is not in use.

Harshman: I water the infield (pitchers circle included) at least three times a day, if not more or less depending on weather conditions. I try to water the infield first thing in the morning. The first watering of the day consists of a heavy soaking, making sure the entire playing surface is well saturated evenly throughout. I then follow up with a water cycle before or shortly after lunch, cutting back on the amount of water from the first cycle of the day but still making sure to water evenly throughout the entire playing surface. The final water cycle is done right before practice or before a game. This cycle is done quickly, applying the least amount of water for the day. If done correctly the playing surface will keep a consistent moisture level for the entire practice/game.

Our infield mix consists of a high density red clay. All maintenance repairs to the infield (pitching lane, batters box etc.) are done with this same clay.

Our infield conditioner helps in maintaining proper and consistent moisture management. Like most infield conditioners this product breaks down over time and I apply fresh, new material when necessary and try to remove whenever possible.

There is no difference in my maintenance practices for the pitcher's circle. All maintenance practices for my clay surface are treated the same way for 100% consistency.

Clay: The upkeep of our clay surfaces (pitcher's circle, home plate and bullpens) consists of daily maintenance and repair of any holes which have resulted from practice or play. Our primary amendment used is a finer granule when compared to a basic

▲ **Field #3:** American Softball Association's Hall of Fame Stadium, Oklahoma City. *Photo courtesy of Tracy Schneweis.* ▲ **Field #4:** Beard Field at Nittany Lion Softball Park, University Park, PA. *Photo courtesy of Paul Curtis.* ▲ **Field #5:** Wilpon Softball Complex: Alumni Field on the campus of the University of Michigan. *Photo courtesy of Jason DeMink.*

amendment. We have found that the coverage and resiliency of the finer granule product is much better than the other products, ultimately countering the additional cost of that product.

Our maintenance routine is the most important component of keeping our clay surfaces safe, firm and resilient, especially with the prevalence of wet conditions in the Pacific Northwest Region. Our clay routine is as follows:

Scarify "action" area; going several directions to break down any high points and loose material.

Pull/brush back using a small broom, any loose material in and surrounding the said hole(s).

Once surface is "bare," we use a small hand sprayer (pump action) to wet the "bare" area.

You will not always need to wet the bare area; there is no need to saturate the surface.

Add the clay product to the hole first, avoid tapering off into the less disrupted and bare surfaces, avoiding this will help prevent the slow build up which commonly occurs. The deeper the hole, the more important it is to add the clay in layers to promote a solid bond and rid the clay of any pockets which may have formed. While layering, a quick mist of water before adding the next layer will promote a solid bond.

When tamping the clay material, use a firm downward action to initially pack the clay into the hole. Inspect layer tamped and add material as necessary. Regardless, finish tamp the surface, overlapping each tamp to produce a smooth surface.

It is important to not build your clay up to "flush" with the pitching rubber or home plate because when adding your finishing amendments such as Turface, you will be adding a layer which will bring the soil above the rubber. Leaving your finished clay work a fraction of an inch below the rubber will promote less digging, and limit the opportunity for the surrounding surfaces to build-up.

Once the clay has been thoroughly tamped, based on observed moisture in the clay, it may be necessary to apply a light coat of water before scarifying over the work to knock down any high spots, loose material, etc… will aide in the bonding of the top layer.

Using a rake, pull any loose material and debris to the center of the circle, dragging it over the clay work you have just completed, the dust and finer particles will work well as a "mortar" to fill any small cracks and openings in the packed clay.

Remove the debris and material collected.

Finish groom/rake the circle.

Based on weather conditions and soil moisture, water as needed and tarp once moisture levels appear adequate.

Tarping is the other critical element of clay maintenance. This very tedious process will help surface hold-up better leading to less disruption and quicker maintenance turnaround.

Schneweis: Because I was new to the position (I started in April of 2013) and to the area, this past playing season was more of an experiment. Coming from a baseball background, I was also new to softball. We tried several types of mound clays and conditioners to see

what one(s) worked best for our fields. I wanted to test them all throughout the spring and summer and see which clay held up the best in the conditions we have here in Oklahoma. I also wanted to see which conditioners worked the best for the different types of clay we were trying.

Most of our events are youth tournaments that start on Friday and end on Sunday. During these events we re-pack all the clay on Monday. We have four fields here and all four receive the same attention on Monday. We don't do much, if anything to the pitching circles again until Thursday. On Thursday morning, we start managing the moisture again and adding water/conditioners as necessary. Friday morning we check all the areas to make sure they are safe and ready for the games, which typically start around 10. Friday night after the last game we re-pack all the clay and have them ready for Saturday morning. Saturday's games usually start at 8:30, so we try and get everything done the night before. After the last game on Saturday, we repack the circles again and have them ready for Sunday's games, which usually start at 8:30. If during the days any of the circles become unsafe with large holes, we will repack in between games. During the College World Series and the World Cup, we re-pack the circle between every game.

How do you keep the rest of the infield skin safe, firm and resilient?

Schneweis: Moisture control is the most important, and challenging, part of maintaining our fields. On a typical Saturday, when we are hosting a tournament, the games run from 8:30 am until 11:00 pm, or later. Games usually last an hour and a half and we have 10 minutes, at the most, to do all of our work: drag, chalk lines/batters boxes, etc. So trying to keep water on them in July in Oklahoma when it's 100 degrees is nearly impossible. We have irrigation heads behind the pitching circles that do a pretty good job of getting some water out, but usually we don't have enough time to do more than just settle the dust down. We try and keep a layer of conditioner (about ½ inch) on top of the fields to help hold some moisture in.

Obviously, weather conditions determine what we can, or need, to do for moisture. If there is no rain forecasted, we will start putting water on the dirt on Wednesday. We soak them all on Wednesday afternoon. We then monitor the fields all day Thursday and add water if necessary. Our goal is to have moisture throughout the profile by the time we leave the complex Thursday night. Friday morning we will check them all and determine if more water needs to be added.

During the day on Thursday, we also try and nail drag and roll the fields. This doesn't always happen; sometimes because of time constraints and sometimes because they don't need it. Rolling the fields with a ½-ton roller has allowed us to be able to seal off the top and hold some of the moisture in. It also "tightens" up the dirt, so it doesn't get as chewed up during play.

Combs: We maintain our infield skin daily with your standard infield maintenance equipment to ensure the safest surface possible. We manage our firmness with moisture and rolling the infield skin with a roller. We cover our infield skin with an amendment layer.

DeMink: We nail drag our skin daily; it helps fill in all those cleat marks. We also use a rain groomer on a Workman vehicle to level any high or low spots around first and second bases. If needed, we will roll the infield skin with a 1-ton roller. And we chain drag and use big brooms daily. Also we will broom twice during games to keep playing surface level and safe during games.

Seybold: The amendment that is currently being used helps retain moisture as well as provide a medium to slide and play the game. The surface is nail dragged at 1/8 inch to try to mitigate as many cleat marks as possible and a 1-ton roller is used sporadically during the season to aid in tightening the top quarter inch of material that is disturbed from the barrage of practice and games.

Clay: Our skin surface is evolved into a complex hybrid mix of several products over the past several years. Our last renovation included the addition of 30 yards of 70:30 (clay:sand) mix. This material was tilled into the existing ag-lime and then graded respectively. Moisture and continual maintenance are the two most important factors to keeping our skinned surfaces resilient. The use of amendments allows us to control our moisture levels, as well as keep the field firm and playable through the winter months. Once a low-spot is identified, address the issue as soon as possible and begin adding material to it. Based on soil composition and condition, tilling of the existing surface before, or during addition of material may be required. This will prevent the scope of your off-season renovations, as well as keep your surface safe and playable. It is a good idea to save and store some extra material for the maintenance of your skin surface throughout the playing season.

Following activity, based on the field conditions, spike or nail drag the skin to break down any chunks, a major disruption. If conditions permit, follow spike/nail drag with a matt/chain drag, allowing skin material to move and redistribute itself into low-spots much more efficiently. When dragging is completed, we remove any debris and foreign materials gathered by our drag mat. Once satisfied with the turnover, soak your skin surface to promote any re-bonding. Allow adequate time for material to settle before next activity. Additional fine tuning will be required around bases and one rake width around the surrounding edge of the skin.

Using a vehicle with worn or bald tread tires will act as a roller and allow the compacting of any loose material. To get optimal firmness and bonding, use a 1-ton ride on roller to compacts any loose material. Follow the process, Drag-Water-Roll-Repeat. Common spots we check are the lead-off/running lanes by all three bases and all position spots. The most observed traffic areas decrease respectively as you move from first base to third around the infield. Sticking to our maintenance program, as well as avoiding activity when conditions are wet and soft, allow us to maintain a resilient surface with a level grade.

What are your short and long term solutions to lip build-up?

Schneweis: Short term, we blow out the lips every Monday. Some weeks we use a backpack blower, others we use a 1-inch hose and wash them out. Once a month we try and "hard rake" them out. We take

a normal garden rake and go at a 45 degree angle and forcefully rake out the edges. We go back and forth a couple of times, one side to the other. It's amazing how much thatch, conditioner, etc., that we remove by doing this. We then rake the "trash" up into a pile and remove it from the field.

Long term is tough for me to say at this point. I would guess we will just re-sod the lips if they ever become unsafe.

DeMink: Lip prevention is done daily with push brooms, backpack blowers, and leaf rakes. Weekly I like to use a hose to blow it out with water. And, if needed, sod replacement.

Harshman: Short term, after daily practices, or normal usage: I come in and leaf rake all lip/transition areas pulling back material onto the infield that has found its way into the turf. After finishing up with leaf raking I use a backpack blower and get the material that has tried to imbed itself deep into the profile.

Long term: After heavy use: (camps, tournaments and weekend series) I will perform the same practices mentioned in the short term. In addition to that I will blow out all lip/transition areas with a water hose that is hooked up to a quick connect water source.

This process in my general maintenance is a delicate procedure. I make sure that the water pressure isn't full blast causing more harm than good to the lip/transition areas. If your pressure is too high you have the potential of blowing out large chunks of your infield requiring you to come back in and make the necessary repairs to the clay infield playing surface. I regulate my water pressure making sure I gradually make small circular stokes along the grass edge blowing out all debris and material are free from working itself deep within the profile. By performing these practices I limit the amount of buildup over time that would eventually create an uneven transition between the clay infield and turf areas.

Seybold: The lips are "washed" out on all off days of all loose clay and conditioner that is worked in to the edge of the grass and during practice days or game days a backpack blower is used to remove as much conditioner as possible without damaging the grass to dirt interface on the edges. During the summer a roll of sod from the ring around the back of the skin is removed and replaced with new "fresh" sod to insure a clean edge is ready to go for the season.

Combs: We try and maintain our edges daily by sweeping or raking them after every use to minimize build-up. We edge the grass frequently to try and maintain a crisp edge. Our long-term solutions would be to flush the edges with a hose to try and flush out any infield material, if the edges are really bad we would just resod. ■