Several factors deserve consideration when applying micronutrients in water to turfs. They include: the weather; the type, nutrient status and growth rate of turfgrass; leaf wetness; the form of the micronutrient; the product application rate, frequency and interval; the spray volume; and the spray tip.

Mn often appear mottled. Young leaves of a turfgrass plant deficient in B may have yellow or white leaf tips and exhibit interveinal chlorosis long before older leaves. The margins of young and middle-aged leaves of plants deficient in Cu often turn yellow, and leaf tips may have a bluish cast. Symptoms of a Mo deficiency are much like that of an N deficiency. The older leaves of plants deficient in Mo 'fire' when the micronutrient is mobilized and moves to young leaves. Leaves of Zn deficient plants are often mottled and stunted, and may roll or appear 'crinkled'. The symptoms of Zn deficiency may be more apparent on younger leaves.

SELECTING AND APPLYING A PRODUCT

A micronutrient deficiency can be corrected by either a foliar or soil application. Micronutrient-containing fertilizer formulations may be in solid or liquid form (Figure 2), and a micronutrient may be mixed with other nutrients (Figure 3, on page 13). Whether in liquid or solid, organic or inorganic form, a fertilizer must be applied uniformly according to label directions.

» **Figure 2.** An example of a liquid fertilizer formulated with macronutrients and micronutrients.

Several factors deserve consideration when applying micronutrients in water to turfs. They include: the weather; the type, nutrient status and growth rate of turfgrass; leaf wetness; the form of the micronutrient; the product application rate, frequency and interval; the spray volume; and the spray tip. The rate at which cells of leaves divide and expand is influenced by light, temperature, moisture and fertility level. The length of time between micronutrient applications can be adjusted according to the rate of growth of the aerial shoots. The recommended product application interval may decrease with increasing plant growth rate.

Several sources of an individual micronutrient may be available for use in turf (Table 3, on page 12). For example, iron (ferrous) sulfate and iron chelates are common sources of iron. Iron chelates are most often more effective as soil applications than ferrous sulfate, which can be highly effective when applied as a foliar treatment. In soil, a ferrous ion (Fe^{+2}) from iron sulfate may quickly be converted to a ferric ion (Fe^{3+}), which is much less available for plant uptake.

Chelates are produced by combining a positively (cation) or negatively (anion) charged micronutrient with an organic compound or chelating agent. The reaction results in a 'protected' micronutrient cation or anion bound in a chemical ring structure. The length of time during which a chelated micronutrient remains in plant available form in soil is influenced by the soil pH, the ion that is in protected form, and the chelating agent. Citric (CIT), acetic [DTPA, diethylene triamine pentaacetic acid; EDTA, ethylene diamine tetraacetic acid; EDDHA, ethylene diamine di (o-hydroxy-phenylacetic acid); and HEDTA, hydroxyethyl ethylene diamine triacetic acid] and oxalic (OX) acids are examples of chelating agents used to produce chelated micronutrients.

When foliar feeding, no more than one-half gallon of a micronutrient-containing solution is usually applied per 1,000 sq. ft. The intent of a soil-drench (one gallon of water or more per 1,000 sq. ft.) treatment is to carry the micronutrient through thatch and into the soil. Turfgrasses most often respond more quickly to a foliar feeding than a granular or soil drench application. The addition of a surfactant may, or may not, be recommended.

Thorough and uniform coverage is essential when applying a micronutrient to turf in water. The diameter of spray droplets varies depending on the spraying pressure and the spray tip installed in the nozzle body on the sprayer boom. The diameter of spray droplets may range from very coarse (> 550 microns) to very fine (< 150 microns).

Table 3.
Several fertilizer sources of essential micronutrients and their approximate nutrient content.[a]

Source	Formula	Approximate micronutrient content (%)[b]
Boron, B		
Borax	$Na_2B_4O_7 \cdot 2H_2O$	11
boric acid	H_3BO_3	17
Chlorine, Cl		
Potassium chloride	KCl	45
Copper, Cu		
Copper oxide	CuO, Cu_2O	75, 89
Copper sulfate	$CuSO_4 \cdot H_2O$, $CuSO_4 \cdot 5H_2O$	25, 35
Copper chelate	Na_2Cu EDTA	13
Iron, Fe		
Ferric oxide	Fe_2O_3	69
Ferrous oxide	FeO	77
Ferric sulfate	$Fe_2(SO_4)_3 \cdot 4H_2O$	23
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	20
Ferrous ammonium phosphate	$Fe(NH_4)PO_4 \cdot H_2O$	29
Ferrous ammonium sulfate	$(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$	14
Iron chelates	NaFeDTPA, NaFeEDTA	10, 6
Manganese, Mn		
Manganese oxide	MnO	41 - 68
Manganese sulfate	$MnSO_4 \cdot 4H_2O$	27
Manganese chelate	Na_2Mn EDTA	12
Molybdenum, Mo		
Ammonium molybdate	$(NH4)_6Mo_7O_{24}$	54
Molybdenum trioxide	MoO_3	66
Sodium molybdate	$Na_2MoO_4 \cdot 2H_2O$	40
Zinc, Zn		
Zinc oxide	ZnO	78
Zinc sulfate	$ZnSO_4 \cdot H_2O$, $ZnSO_4 \cdot 7H_2O$	35, 23
Zinc chelate	Na_2Zn EDTA	14

[a] From: Carrow, R.N., D.V. Waddington and P.E. Rieke. 2001. *Turfgrass soil fertility and chemical problems: assessment and nanagement.* Hoboken, NJ: John Wiley & Sons, Inc.
[b] The actual percentage of the micronutrient may vary depending on the purity and source of the product.

GUARANTEED ANALYSIS

Magnesium (Mg)....1.00%
1.00% Soluble Magnesium
Sulfur (S)....3.50%
3.50% Combined Sulfur
Boron (B)....0.02%
Copper (Cu)....0.25%
0.25% Chelated Copper
Iron (Fe)....4.00%
4.00% Chelated Iron
Manganese (Mn)....1.00%
1.00% Chelated Manganese
Molybdenum (Mo)....0.0005%
Zinc (Zn)....0.60%
0.60% Chelated Zinc (Zn)

Derived from: Magnesium Sulfate, Sodium Borate, Copper Glucoheptonate, Iron Glucoheptonate, Manganese Glucoheptonate, Zinc Glucoheptonate, and Sodium Molybdate

- ***Optimal liquid foliar formulation of essential plant nutrients***
- ***Aids in the prevention and correction of micro-nutrient deficiencies***

RECOMMENDED RATES

Turf (Fairways, Greens & Tees): Apply 2-6 oz. per 1,000 sq. ft. or 3-6 quarts per acre in enough water to cover.

Trees & Ornamentals: Apply 4-6 quarts per 100 gallons of water as a drench or foliar spray. Repeat as needed.

PRODUCT INFORMATION

Harrell's MAX Minors (complete minors package) is a liquid foliar formulation of essential nutrients and micronutrients to aid in the prevention and correction of deficiencies. The ratio of minors in Harrell's MAX Minors micronutrient package has been optimized for higher pH soils where trace elements often become unavailable to the plant. In alkaline soils, Harrell's MAX Minors will remain available longer than many other products. Harrell's MAX Minors can be applied with most pesticides and fertilizers except high phosphate materials. The addition of a non-ionic surfactant will aid surface coverage which will help leaf absorption.

DIRECTIONS FOR USE

Harrell's MAX Minors may be tank mixed with most liquid fertilizer and pesticides; however a jar compatibility test should be performed on unknown combinations.

PRECAUTIONS

Shake well before each use. Avoid getting in eyes, mucous membranes or on skin. Use of side-shielded safety glasses is recommended. Use with adequate ventilation. Keep container capped when not in use. Do not contaminate feed, seed, or water supplies. Avoid spraying on concrete or painted surfaces as staining may occur.

Keep away from Children.

FIRST AID

Skin: Remove contaminated clothing. Wash with plenty of clean water and soap. Consult a physician.
Eyes: Rinse with clean water for a minimum of 15 minutes. Seek medical attention.
Internal: Drink 2 glasses of water. DO NOT INDUCE VOMITING. Seek medical attention at once.

STORAGE AND CONTAINER DISPOSAL

Store this product in a dry place, in original container only. Keep lid tightly closed. Keep away from open flame or intense heat. Triple rinse container and offer for recycling or dispose of in accordance with federal, state and local authorities.

CONDITIONS OF SALE

Seller warrants that products will be labeled as required under state and federal laws and that they conform to the label description. Any non-conformance must be reported in writing to Seller within Thirty(30) days after purchase as a prerequisite to maintaining any claim against Seller. Buyer agrees to inspect all products purchased immediately upon delivery. The seller's liability under this warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability and fitness for a particular purpose. There are no warranties which extend beyond this statement.

Figure 3. An example product label identifying the micronutrient sources and application rates.

Manufacturers often rate the effectiveness of each type of spray tip as good, very good, excellent or not recommended, for specific applications (e.g., broadcast liquid fertilizer; contact and systemic fungicides, herbicides and insecticides; …).

Since an application may, or may not result in a visual improvement in foliage color or turfgrass health even though test results indicate that one or more micronutrients are in the low or deficient ranges, it may be advantageous to treat a limited amount of turf with a product of interest before making a broadcast application over the entire sports field. ■

Dr. Tom Samples is an extension specialist for turfgrass management; Dr. John Sorochan is associate professor, turfgrass science and management; and Adam Thoms is research leader, all at the University of Tennessee in Knoxville. Brad Jakubowski is an instructor at Doane College, Crete, NE.

>> **FIGURE 1**. A dormant but extremely dense Riviera bermudagrass field in early December 2012 at Wilson Memorial HS, Waynesboro, VA (photo courtesy of Jimmy Rodgers).

Inside look at the turf team at Virginia Tech

INSTEAD OF A TRADITIONAL ARTICLE* on the STMA President for this month's issue, I asked for the opportunity this year to tell you a little bit about the turfgrass program at Virginia Tech and some of the great work my colleagues are doing that might apply to you.

Team: a number of persons associated together in work or activity. Being a part of a team certainly does not guarantee success, but teams that continually strive to improve and work together (i.e. demonstrate teamwork) will most likely perform at the top of their abilities. Nearly every month, *SportsTurf* features an award-winning team of sports turf managers recognized as 'Field of the Year" winners. A common theme in these articles is the value of teamwork. I received exceptional mentoring regarding the importance of a team and teamwork as a young faculty member at Mississippi State University from Dr. Jeff Krans. Since those formative years in my professional career, I have made it a point to emphasize to my colleagues how much I value being a part of a team. Something that gives the members of the turfgrass program at Virginia Tech great satisfaction is how our clientele refer to us as the VT Turf Team. And nowhere have I said being part of a team is easy—securing the information for this article and getting a cover photo of the team was akin to herding cats!

The VT Turf Team's collaboration across departments, programs, and colleges in our teaching, research, and extension programs has been cited by many administrators as a model for other programs at Virginia Tech to emulate. Our VT Turf Team is also much more than just the faculty, staff, and graduate students in our traditional academic programs, but it also includes our staffs that manage all VT athletic and recreational sports fields. Our athletics turf and recreational sports programs support turfgrass research, participate in our research field days, and are constantly "on call" for field and facility tours, something very important to our fund-raising and student recruiting activities. We also proudly claim as team members a large number of allied extension agents, private individuals, industry, and professional association cooperators around the state that assist us with financial support, on-site research opportunities, and the hosting of a variety of outreach programs.

I want you to meet a few of my VT team membersand I asked them to join me in providing a brief highlight of some of our sports turf-related research projects. These reports are but very small parts of their research programs, and if you have further questions of my colleagues regarding this or other projects they are leading, please be sure to get in touch with them by way of the contact information available at www.vt.edu.

BERMUDAGRASS EXPANSION ON VIRGINIA SPORTS FIELDS-Mike Goatley. Virginia's transition zone climate makes it possible to grow either cool-season or warm-season grasses on athletic fields, but none of them very well. Either type of grass is going to regularly struggle from an extreme summer or winter season. A part of my applied research program is variety evaluation and my turfgrass program manager, Whitnee Askew, and I have spent a great deal of time assessing bermudagrasses that we believe are well suited for athletic field

The data continually indicate what great potential the latest generations of cold tolerant vegetative and seeded bermudagrasses have for sports fields.

use in our climate. The data continually indicate what great potential the latest generations of cold tolerant vegetative and seeded bermudagrasses have for sports fields.

Depending on your perspective (see Dr. Askew's research brief below), bermudagrass is either an outstanding sports turf grass OR it is one of the world's worst weeds. For sports turf, bermudagrass offers transition zone sports field managers the opportunity to take advantage of the exceptional density and aggressive growth rate of this grass. In particular, these grasses have now made their way onto athletic fields throughout the Valley and Ridge region of Virginia at elevations of 2,300 feet or higher. As for any natural grass field, they still must be used and managed appropriately to meet expectations, but with proper traffic management, these fields are providing exceptional playing surfaces even as dormant turfs.

The one point of caution I bring to any facility considering a conversion is the intensive mowing requirement of bermudagrass in the summer. However, if this maintenance requirement is properly addressed, the end result is usually a more uniform playing surface and fields that require much less irrigation and pesticide use than comparative cool-season fields.

The most recent success story in Virginia's Shenandoah Valley is Wilson Memorial HS where football coach (and VSTMA member) Jeremiah Major seeded Riviera bermudagrass the summer of 2012. Jeremiah and his team delivered an exceptional field by the season opener in August, but even more impressive was the quality of his turf well into the playoffs in late November (Figure 1). The performance and condition of these fields certainly captures the attention of opposing coaches, players, and parents and has led to many fact-finding inquiries about a grass that they previously considered only to be a serious weed.

BERMUDAGRASS/WIREGRASS CONTROL–Shawn Askew. Dr. Askew has statewide responsibilities for developing weed management systems in turfgrass. He conducts weed control, herbicide physiology, and weed ecology experiments in all types of turf including athletic fields. His graduate students are currently working on several projects that may impact weed management in athletic fields.

In Virginia's climate, bermudagrass is both a desirable turf and a weed. Dr. Askew and his graduate students have worked hard over the past 8 years to develop selective bermudagrass control programs for cool-season turf, especially for Kentucky bluegrass athletic fields. Fenoxaprop + triclopyr programs were developed years ago in North and South Carolina and work great for tall fescue turf. In lower height turf and Kentucky bluegrass, the ester formulation of triclopyr can be extremely injurious to Kentucky bluegrass turf and fenoxaprop is much more injurious to immature turf of any species when compared to mature turf. Both of these phenomena can be problematic for athletic field management where Kentucky bluegrass and lower mowing heights are com-

» **FIGURE 2.** White tissue symptoms that normally occur from the topramezone treatments (center plot is topramezone alone) are reduced or nearly eliminated and bermudagrass control increases dramatically when topramezone is tank-mixed with triclopyr (plots on left or right) (photo courtesy of Shawn Askew).

mon and immature turf will always be present due to the need to manage wear areas.

Dr. Askew's research suggests that fenoxaprop + triclopyr should only be used in early spring or late fall where immature turf is less prevalent and should be replaced with mesotrione or mesotrione + triclopyr at low rates during stressful periods of summer. Applications of either mesotrione or fenoxaprop mixed with triclopyr can effectively control bermudagrass in cool-season grasses. Just remember to reduce triclopyr rates in hot weather and on Kentucky bluegrass, switch from fenoxaprop to mesotrione both to save money and reduce potential damage to the bluegrass during stressful summer weather, and concentrate on fall treatments to get the best kill (repeat treatments at a 3-4 week interval).

Two new herbicides that are currently under investigation by Dr. Askew's group include topramezone and metamifop. Both herbicides show great promise for selective bermudagrass control and topramezone could be registered within the next year (Figure 2). Both herbicides work better when mixed with triclopyr but offer superior turf safety and bermudagrass control to other herbicides currently on the market. No herbicide, however, will control bermudagrass alone but must be mixed with other herbicides and applied 4-6 times per year in a program approach to bermudagrass eradication.

TURF TOLERANCE TO RIGID TURF PROTECTION SYSTEMS–Erik Ervin.

Dr. Erik Ervin is a Professor of Turfgrass Physiology in the Crop and Soil Environmental Sciences department of Virginia Tech and has primary responsibilities in teaching and advising in the undergraduate program. This research brief summarizes work supported by VT Athletics and the U.S. National Park Service and was completed in 2012 by M.S. student John Royse.

The presidential inauguration, the national book festival, the solar decathlon, and a U2 or Dave Matthews Band concert: what do these events have in common? They are all multi-day set-up and take-down events (often involving cranes) that take place on natural turfgrass surfaces (e.g., the National Mall and MLB fields) with thousands of attendees. Many times the activities are so intense that major turf death occurs and complete re-grassing is required. Managing or softening the conditions that cause major turf loss, however, is preferred. Unfortunately, there have been almost no scientific studies investigating the positives and negatives of current practices.

In 2010 and 2011 we conducted multi-season event cover simulation trials to determine how long a mature tall fescue turf (2.5 inch mowing height on a silt loam soil) could survive and what some of the controlling factors might be (e.g., light, compression resistance, soil moisture, temperature). Two commercially available rigid high-density polypropylene covers were compared to plywood-alone or plywood over Enkamat (Table 1). Terratile is a single-sided, white, translucent cover with foot pads and air holes used primarily for seating or foot-traffic protection, while Matrax LD is a double-sided, white, translucent cover with no air holes used primarily for vehicle-traffic protection. Each spring, summer, or fall season covers remained on the turf for 2, 4, 6, 8, 10, 12, 14, 16, 18, or 20 days giving us a look at turf persistence and recovery every 2 days during a 3-week period (Figure 3). Using linear regression we were able to estimate how long tall fescue could be covered (and driven over daily with a truck) and not have more than 40% turf loss (Table 1).

We found that light availability played a major role in turf persistence and recovery. The translucent Terratile and Matrax prod-

Table 1. Light transmission, average maximum high temperature under cover, and the predicted days until 40% or greater tall fescue loss following covering of various turf protection systems in summer or fall/spring.

		High temperature under cover	Number of days under cover before >40% turf loss, tall fescue	
Cover name	**Light transmission**	**Mean across 2 summer seasons (°F**	**Summer[1]**	**Fall/Spring[1]**
Terratile	25%	108	10	>20
Matrax LD	5%	100	12	>20
Plywood over Enkamat	0%	101	1	5
Plywood	0%	104	1	5

[1]Average high air temperatures during the two summer test periods was 94°F, while that over the four spring and fall test periods was 70 °F.

JOHN MASCARO'S PHOTO QUIZ

John Mascaro is President of Turf-Tec International

Can you identify this sports turf problem?

Problem: Thin and stressed turf with trash can barrels on field
Turfgrass area: Intramural field
Location: Tallahassee, Florida
Grass Variety: 419 Bermudagrass

Answer to John Mascaro's Photo Quiz on Page 33

Background illustration courtesy of istockphoto.com

>> **FIGURE 3**. Differential tall fescue response after covering for 6 days in the fall with Matrax/Terratrak (top) or Plywood+Enkamat (bottom) (photo courtesy of John Royse).
>> **FIGURE 4**. Spring Dead Spot on a Riviera bermudagrass athletic field in Rocky Mount, VA (photo courtesy of David McCall).

ucts allowed 5 to 25% of photosynthetically active radiation through to the leaf blades when measured at solar noon. During cooler spring and fall periods this resulted in almost complete turf persistence and recovery even when covered for the entire 20-day test period, while both plywood treatments allowed for only 5 days of cover. During summer, extra light transmission through Terratile resulted in significantly higher temperatures reducing turf persistence to 10 days compared to 12 days for Matrax. Plywood or plywood over Enkamat resulted in almost complete turf death after only 2-4 days of cover in the summer. Our results were clear and consistent: Use of a rigid cover that allows some photosynthetically active light to reach the turf canopy is of primary importance, with air exchange and compression resistance being important, but secondary.

SPRING DEAD SPOT (SDS) MANAGEMENT IN BERMUDAGRASS – **David McCall**. David is a research associate and PhD candidate in the Plant Pathology, Physiology, and Weed Science Department of Virginia Tech. He has primary responsibilities in turfgrass pathology.

In Virginia, where a growing number of athletic facilities have transitioned to improved varieties of bermudagrass, the most frequent disease-related question I hear is "What can I do about my Spring Dead Spot?" As most who have managed bermudagrass know, spring dead spot (SDS) is the most common and damaging disease of bermudagrass (Figure 4.). Not only is the disease highly unsightly, but a severe patch can be depressed to bare ground, often half an inch or more below the surviving turf stand. This can play havoc on playability and increase the chance for athlete injury.

For decades, a standard recommendation for suppressing SDS has been to use ammonium sulfate as a primary nitrogen source throughout the summertime. This was based on research on one of the pathogens, *Ophiosphaeralla herpotrica*, which is most commonly found throughout the Great Plains and other Midwestern states. The general belief was that all species of the causal agent (there is also *O. korrae*, most common in Southeastern US, and *O. namari*, most common in Australia and New Zealand) would respond the same to nitrogen sources. However, research from the turfgrass pathology program at North Carolina State clearly demonstrated that *O. herpotrica* and *O. korrae* responded differently when clean bermudagrass was inoculated. *O. herpotrica* responded as expected, and was suppressed with ammonium sulfate. *O. korrae*, on the other hand, did not respond to this, but did to calcium nitrate. While the impact on disease activity is not fully understood for each species, we do know that sulfur-based nitrogen sources will lower pH in the upper rhizosphere, and most nitrate sources have little effect on pH.

Because of the widespread problem for turf managers in Virginia, field research trials were initially established on sites with severe SDS epidemics in the spring of 2010 to see how quickly this new guideline may reduce disease. Trials were established on one soccer field (Southwestern Virginia), two golf course fairways (Central Virginia and the Eastern Shore), and one research plot at the Hampton Roads AREC in Virginia Beach. Plots with pre-existing SDS were fertilized with ammonium sulfate (21-0-0), calcium nitrate (15.5-0-0), or soluble urea (46-0-0). Two additional management strategies were applied to test confounding effects of nitrogen source. Plots were split to test whether fall applications of fungicides can speed the recovery of SDS. Interaction with late summer vertical mowing was also examined.

While the NC State research showed dramatic results for new patch development, incorporating various nitrogen sources into pre-existing conditions in our trials has not

Table 2. White grub counts in 2011 Turfgrass Soil Insecticide Efficacy Trials, Tazewell Co., VA.

Treatment/Formulation/ Application Timing1	Application rate (amt product/acre)	White grubs per sq ft (± SEM)2
Untreated check	—	24.13 (3.48) a
DPX-HGW86 20 SC April	8.0 fl oz	23.25 (5.22) a
Merit 75 WP April	6.4 oz	22.00 (4.26) a
Zylam 20SG July	32.0 oz	19.00 (3.42) ab
Allectus GCSC April	4.5 pints	9.00 (1.63) b
Acelepryn 1.67 SC July	8.0 fl oz	2.00 (1.08) c
DPX-HGW86 20SC July	8.0 fl oz	0.75 (0.48) c
Acelepryn 1.67 SC April	8.0 fl oz	0.00 (0.00) c
Merit 75 WP	6.4 oz	0.00 (0.00) c

1Early application: 20 April; late application: 19 July

2Means within a column followed by the same letter are not significantly different at $P < 0.05$ according to LSD tests.

reduced disease as rapidly. To date, results from site to site have been highly inconsistent, but no fertility regimen in combination with other management strategies has proven to be a silver bullet. What appears to be effective in one plot may have little to no response in the next. This inconsistency led to us to wonder whether each site had mixed populations of the SDS pathogen. If both species of *Ophiosphaerella* are present at one site, then no one nitrogen source would suppress the disease. One of the treatments included both ammonium sulfate and calcium nitrate, but this still has not adequately suppressed disease. While the current research will continue for at least 1 more year, we are shifting our primary focus to understanding the population dynamics across the state and within a given field. In collaboration with the Plant Disease Clinic at Virginia Tech, we are working to develop a rapid identification test that will allow turf managers to know what is causing the majority of their SDS problems. While SDS suppression strategies are still evolving, we are growing increasingly confident that our work will improve sports turf managers' ability to make well informed and site-specific management decisions.

WHITE GRUB CONTROL - Rod Youngman. Dr. Youngman is an extension entomologist with statewide responsibilities in integrated pest management in turfgrass, field corn, and forage crops.

White grubs have been the major focus of my applied research and extension outreach programs in Virginia. These root-feeding larvae feed on all of Virginia's sports turf grasses from mid-spring until killing frost, but they cause the most damage on cool-season athletic fields during the heat of summer. Damage from a heavy infestation of grubs is often made worse by the burrowing of foraging animals and birds such as skunks, raccoons, and crows. The damage can literally make fields unfit for play due to the surface damage and the subsequent poor footing of damaged turf (Figure 5).

The results of this research (Table 2 indicate several important findings regarding chemical grub control. The mid-April applications of the experimental DPX and Merit 75 WP (imidacloprid) treatments did not perform well, but at the late application (same rates) they ranged among the top performers. DPX-HGW86 is being positioned as a rescue treatment by its company. Although the traditional grubicide Merit no longer has the staying power (April-August white grub control) it once enjoyed, the performance of its July application is directly in line with the white grub life cycle. White grub egg-laying typically begins mid-July and peaks the first-second week of August in our area. Acelepryn (chlorantraniliprole) provided excellent grub control in either early or late season applications; the season-long grub control from its April application and its additional control prospects for turf caterpillars makes this a very promising insecticide for many turf uses.

>> **FIGURE 5**. Damage to a Kentucky bluegrass/perennial ryegrass athletic field from skunks foraging for white grubs.

In addition to continuing work in this area, we have also started evaluating entomopathogenic fungi and nematodes as biological control agents against annual white grubs. If successful, these combinations might greatly expand our options in biological grub control.

DALLISGRASS CONTROL IN BERMUDAGRASS - Jeffrey Derr and Adam Nichols, Hampton Roads Ag. Res. and Ext. Center. Dallisgrass *Paspalum dilatatum* is a warm-season perennial that spreads by short rhizomes as well as by seed. Dallisgrass clumps expand over time due to rhizome growth. Its wide blades and tall seed heads make the weed especially apparent in bermudagrass turf. Dallisgrass is a troublesome perennial grass in a number of turf situations, including sports turf. It invades both warm and cool-season turfgrass, where there are limited control options. MSMA, the most commonly used herbicide for dallisgrass control, currently can only be used in golf courses, sod production, and rights of way areas. It is unclear what turf labels will exist for MSMA in the future. Additional control options are needed for this weed in turf.

We have been investigating herbicides, herbicide combinations, and herbicide application timing for dallisgrass control in bermudagrass. The herbicides tested include Revolver, Celsius, Tribute Total, and Monument. We have included MSMA for comparison. All of these herbicides will injure dallisgrass, although this weed will recover from single applications. Label restrictions prevent making more than two applications per season for some of these products. We have rotated herbicides in our repeat applications to stay within label restrictions. We have tested multiple spring, multiple fall, and spring followed by fall applications. We compared broadcast applications to spot treatment. For certain herbicides, a higher dose can be applied using a spot treatment, although only about one quarter of the total turf area could be treated using these doses.

>> **FIGURE 6**. Dallisgrass is very noticeable in bermudagrass due to its wider blades and tall seed heads.

Two applications of Celsius plus Revolver in spring provided 45% dallisgrass control in summer, but the dallisgrass com-

Continued on page 45

Clarifying and magnifying concepts in the pesticide industry

I SAT IN ON AN INTERESTING DISCUSSION at the National Entomological Society of America meeting in Reno, NV in late 2011. There were talks on the uses, advantages and disadvantages of simultaneous pesticide combinations in integrated pest management strategies. Here are some of the highlights:

First of all, the terminology is confusing and certain words mean different things to different people. Let me define a few terms according to the Insecticide Resistance Action Committee (IRAC) before I go too far.

Pesticide combinations: applications of two or more compounds to the same pests at the same time. Specific examples are tank mixes and premixes.

Tank mix: a mixture of two or more products (they don't just have to be insecticides) onsite or on a mix/load pad by an applicator. Each product is often applied at a high labeled rate. Sometimes a "tank mix" may be thought of as mixing one product with water in a tank, but that is not how I'm using the term in this article.

Premix: a commercial product containing two or more active ingredients. At least one active ingredient is usually applied at a lower rate than if used alone. This "premix" category is different from the use of something like water-soluble packaging of a single insecticide.

Why would anyone use a combination of products, rather than just applying one product at a time? There can be pros and cons, either way. The most common reason to combine pesticides is to kill more pests with one application. Many of the newer insecticides have fewer target pests (are "narrow-spectrum") and may have different routes of entry (contact vs. plant systemic), so if you apply two or more at one time, then you have a more "broad-spectrum" treatment. Other benefits may include reducing transportation costs (if you kill most pests initially, there may be fewer call-backs), like saving on fuel, reducing the amount of packaging, decreasing possible turf injury from repeated traffic or soil compaction and decreasing the spread of disease or pests on equipment. Client satisfaction (at least in agriculture) tends to be higher when mixtures are used, and mixtures may be less expensive than do-it-yourself tank mixes.

Another reason to use a mixture or pesticide combination is to slow down the development of resistance in some pests. However, this is not the typical motivation of applicators, and I would appeal to you to weigh the pros and cons of this when choosing your pesticide inventory. I was amazed that in agriculture, a lot of insecticide mixtures have been used over the last 50+ years—e.g., abamectin (Avid) plus thiamethoxam (Meridian) on pears against psyllids and aphids. The list was so long, I couldn't write down all of the combinations.

Mixing products is not as easy as it sounds. With any kind of mixture, there are some things to watch out for. It is possible to get "**antagonism**" between compounds, which means that the mixture is less effective than when the single products are used alone. There is also the risk of plant damage or "**phytotoxicity**," which is more likely to occur when mixtures are applied to stressed plants (e.g., drought-stress), but separate applications of the compounds would not hurt a plant. And, "**physical incompatibility**" can happen if two compounds or formulations react to each other or physically can't combine (an issue of compatible solubility). The result could be a big glob of goo in your spray tank.

Some cautions to be aware of: Avoid mixing insecticides that have the same "mode of action" or are in the same chemical class. From a resistance management perspective, if an insect is resistant to one insecticide (e.g., bifenthrin), then what good would it do to add another pyrethroid (e.g., permethrin, deltamethrin, lambda-cyhalothrin, etc.) to the mix? There could be cross-resistance within the same chemical class or even across other classes, so you would only be exerting the same selection pressure to the pest. For example, carbamates and organophosphates act essentially the same way on an insect, and pyrethroids and DDT similiarly have some cross-resistance. Hopefully, you remember that a mode of action is how an insecticide acts (e.g., interferes with the sodium channel) at its target site (e.g., the nervous system) within the insect.

Another caution is to avoid using the same mode of action (single product or mixture) against the same generation or life stage of the target pest. This may be easier said than done in the southeastern US, especially Florida and the Caribbean, where we have overlapping life stages of pests nearly year-round. Ideally, one treatment could be used to knock out most of one pest generation, then if needed, you could come back to treat the next generation or whenever damage reoccurs.

Similarly, if a treatment of some product doesn't work the first time, don't keep applying it again in the hopes that attempt #2 or #3 might be more worthwhile. Doing the same thing over and over again when you know it doesn't work is insanity (and arguably unethical if you're getting paid for the job). Be aware that treating with a brand name product and at the same time with a generic product at the highest labeled rates equals a 2X application, which is illegal. Again, the goal is to reduce selection pressure and use products wisely, not nuke everything. Modes of action can be determined by finding the "Group" number on a product label or by looking up the active ingredients on the IRAC website (http://www.irac-online.org).

The last caution I heard at the meeting was that premixes should not be used unless all components within the product are needed.

ADVANTAGES, DISADVANTAGES OF MIXES

The advantages and disadvantages of tank mixes and premixes were thoroughly discussed at this meeting. For example, commercial premixes have the advantages of being convenient to use, the active ingredient rates are unchangeable, the component rates and formulations are optimized during development, no mixing or stability issues should exist, and at least one component is usually applied at a lower-than-labeled rate. Some disadvantages include the inability of an applicator to change the active ingredients, all target pests should be present at the same time, and premixes may have been designed for specific pests or regions of the US but could be used outside of the optimal treatment zone. From an economic standpoint, premixes may be created by manufacturers as part of a post-patent marketing plan to obtain a licensing extension.

Some advantages of tank mixtures include giving the applicator some flexibility to provide treatments that fit the pest control need at that time, and they help to reduce any excess pesticide inventory that might exist. However, the flip side is that creating a tank mixture is less convenient, it's potentially hazardous to people who are not trained to properly mix products, "homemade" tank mixes may not be as stable as a premix, and the products being combined tend to be mixed at the highest labeled rates.

According to IRAC there are some requirements for a mixture to be considered effective. First, all toxins should persist the same length of