Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Turf Management
Dec. 2007
TM-6*

Managing Bermudagrass Athletic Fields

J.T. Brosnan and J. Deputy
Department of Tropical Plant and Soil Sciences

Bermudagrass (*Cynodon* species) is the most commonly used turfgrass on athletic fields in Hawai'i. This grass, which propagates via stolons and rhizomes, is an aggressively growing species that provides a dense, resilient athletic field playing surface. Bermudagrasses grow best in full-sun conditions at air temperatures between 80 and 95°F. Both common and hybrid bermudagrasses can be used on athletic fields in Hawai'i.

This publication outlines strategies for managing bermudagrass athletic fields in Hawai'i.

Common bermudagrass (*Cynodon dactlyon*)

Improved common bermudagrass cultivars such as 'Yukon', 'Mirage', 'Pyramid', and 'Riveria' have become available in recent years. These can be established from seed and offer greater aesthetic and functional quality over older common bermudagrass cultivars. The cultivar of common bermudagrass best suited for use on athletic fields is 'Riveria', as it has been found to be highly tolerant of foot traffic.

Hybrid bermudagrass (*Cynodon dactylon* x *Cynodon transvaalensis*)

Hybrid bermudgrasses are interspecific crosses of common bermudagrass and African bermudagrass (Cynodon transvaalensis). These hybrids do not produce viable seed and must be established using sprigs, plugs, or sod. Various hybrid cultivars can be used on athletic fields, including 'Patriot', 'MS-Choice', 'GN-1', and 'Tifsport', but 'Tifway' (also known as 'Tifton 419') has become the industry standard. 'Tifway' is highly tolerant of athletic field traffic and possesses a high recuperative potential. 'Tifway' bermudagrass is commonly used in stadiums throughout the National Football League and Major League Baseball.

Mowing

Proper mowing promotes rooting, tiller density, and uniform growth. The best maintenance practice for bermudagrass athletic fields is to mow frequently at a low height of cut. This practice stimulates new growth and increases the density of the turfgrass stand. Mowing at heights lower than recommended encourages thin, weak turf that is less tolerant of athletic field foot traffic Suggested heights of cut for both common and hybrid bermudagrass are listed in Table 1.

Mowing frequency is based on the general rule of removing no more than one-third of the leaf blade at any one time. A greater percentage of leaf tissue is removed with infrequent mowing. This practice results in scalping, which reduces the traffic tolerance and recuperative potential of the field. When mowing frequently, it is not necessary to collect clippings; however, if mowing is delayed and clippings become excessive, they should be removed.

Reel-type mowers (Figure 1) provide the highest quality cut on athletic fields. Hybrid bermudagrasses require a reel mower, while rotary mowers can be used on common bermudagrass selections maintained at heights of cut greater than 1 inch.

*This revises *Maintaining bermudagrass athletic fields* by D. Hensley, J. Deputy, and J. Tavares, March, 1999.

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Andrew G. Hashimoto, Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

Table 1. Mowing heights for bermudagrass sports fields.

Grass	Maintenance level	Mowing height (inches)	Mow when grass reaches this height
Common bermudagrass ('Riveria,' 'Yukon,' 'Sundevil II,' etc.)	Low	1–1½	1½–2
	High	¾	1
Hybrid bermudagrasses ('Tifway', 'Tifway II', 'MS-Choice')	Low	½–¾	¾–1

Fertilizer applications

A proper fertilization program is required to provide good bermudagrass color, quality, traffic tolerance, and recuperative potential. A routine maintenance fertilizer for bermudagrass should have an N-P_2O_5-K_2O ratio of approximately 4:1:2 or 3:1:2. Nitrogen is the nutrient that has the largest effect on bermudagrass quality. Bermudagrass athletic fields require 1–1½ pounds of nitrogen per 1000 square feet, per growing month. It is important that soluble nitrogen sources (i.e., urea, ammonium nitrate, ammonium sulfate) are used to quickly provide the plant with nutrients needed to recuperate from traffic stress. However, do not apply more than 1 pound of soluble ("quick-release") nitrogen per 1000 square feet per application. Apply approximately ½ inch of irrigation following applications of soluble nitrogen fertilizers. This will reduce loses from volatilization and prevent "burning" of the bermudagrass foliage.

Slow-release nitrogen sources such as isobutylidene diurea, milorganite, and sulfur-coated urea can be used on bermudagrass athletic fields. These materials can be applied less often, and at higher rates, than soluble sources. While applying these materials can minimize the potential for foliar burn and promote more consistent bermudagrass growth throughout the entire season, nitrogen release rates in these fertilizers can vary with soil temperature, soil moisture, and microbial activity. To promote turf recovery, it is important that nitrogen be immediately available to the plant following traffic stress. A program incorporating both quick and slow-release fertilizers is recommended.

Each fertilizer application should deliver ⅓ pound of potash (K_2O) per 1000 square feet. Phosphorus (P) needs should be determined based on a soil test. The tests should be done every 2–4 years to assess nutrient status as well as pH.

1. Reel-type mower (photo, P. Curtis)

Periodic applications of iron (Fe) can improve turf color without causing additional leaf growth. Granular and liquid sources of iron are commercially available.

Soil pH

The optimum soil pH for bermudagrass is between 6.0 and 7.0. The species can tolerate a pH range from 5.5 to 8.0. Most Hawai'i soils have pH within the acceptable range. Soil tests should be conducted every 2–4 years to assess soil pH and nutrient status. Should soil pH move out of the acceptable range, most soil testing laboratories will provide recommendations to correct the problem.

Irrigation

Irrigation is required to provide a strong bermudagrass turf tolerant of athletic field traffic. Actively growing

2. Underground, automatic irrigation system
(photo, T.J. Serensits)

3. Aboveground irrigation gun used for athletic field irrigation

plants contain more than 75 percent water by weight. An underground, automatic sprinkler system is most often preferred when irrigating a frequently used bermudagrass athletic field (Figure 2); however, aboveground systems can be suitable in some situations.

Irrigation is needed to supplement rainfall. Actively growing bermudagrasses require (on average) 1–1½ inches of water per week. This amounts to 635–940 gallons of water per 1000 square feet each week, depending on the size of the field. Try to irrigate no more than twice a week, applying about ¾ inch of water each time. Do not irrigate daily with light amounts of water, because this encourages shallow rooting and increased pest problems. Try to moisten the soil to a 6-inch depth with each irrigation event. Watering during the early morning hours will limit the amount of time leaf tissue remains moist and reduce the amount of water lost due to evaporation. Coordinate irrigation with scheduled activities, applying water at least 24 hours before the field is to be used.

While underground, automatic irrigation systems are the best tool for irrigating bermudagrass athletic fields, certain professional-grade gun-sprinklers can be used in some cases (Figure 3). However, irrigation coverage uniformity is comprised with these systems, as applications are highly subject to wind distortion. Home lawn sprinklers, even traveling models, are not adequate for athletic fields.

4. Vertical mower blades (photo, J.A. Borger)

Dethatching

Thatch is a layer of undecomposed organic matter intermingled with live plant stems at the soil surface. Periodic removal of thatch with a "vertical mower" (Figure 4) is necessary to properly maintain bermudagrass athletic fields. Visually examine thatch buildup by pulling cores from different areas of the field (Figure 5). Action is required if the layer of thatch is between ½ and ¾ inch thick. Vertical mower blades penetrate into the playing surface, removing thatch buildup at the soil-turfgrass interface. Blades should be spaced approximately 1 inch apart for bermudagrass. Mow in two directions at right angles (Figure 6). Debris (thatch) brought to the surface

5. Core pulled from an athletic field to examine thatch buildup

6. Bermudagrass athletic field after vertical mowing (photo, L. Yoder)

after vertical mowing can be raked, vacuumed, or blown off by hand or with one of the many commercially available units (Figure 7).

Note that the process of vertical mowing places a considerable stress on the existing turf canopy. To promote recovery, vertical mowing should be done in early spring and again in midsummer when conditions favor bermudagrass growth. Irrigate deeply after vertical mowing. Fertilize with 1 pound of ammonium sulfate per 1000 square feet no later than one week after vertical mowing to stimulate growth. Irrigate immediately after fertilizing. The rate of recovery time varies with climatic conditions and soil fertility levels. Note that vertical mowing can expose weed seeds, and application of a preemergence herbicide, such as oxadiazon (Ronstar® G), within a week of vertical mowing should be considered.

7. Commercially available vacuum unit to collect debris after vertical mowing (photo, L. Yoder)

Soil compaction

Soil compaction reduces athletic field playing quality. The development of compacted soil conditions on an athletic field is directly proportional to the amount of use the field receives. Compaction reduces pore space in the soil, which in turn reduces the amount of oxygen and water available for root growth. Consequnetly, turf vigor gradually declines and the field will not recover from the stress imposed by foot traffic. Voids (bare spots) in the turf canopy are also subject to weed invasion. Compaction is usually most severe on areas of the field where foot traffic is the most concentrated, such as between hash marks (football), in front of goals (soccer and football), and along sideline and bench areas (Figure 8).

Core aeration, sometimes referred to as hollow-tine cultivation, is the practice of removing small soil cores from the root zone. This is one of the most important management practices for bermudagrass athletic fields. Core aeration relieves compaction, allows better penetration of oxygen into the soil, encourages deeper rooting, and increases water infiltration, and reduces thatch buildup.

Core aeration equipment uses special coring tines to remove soil cores from the field (Figure 9). These coring tines can be configured to remove cores ranging in size

8. Effects of soil compaction on areas receiving high foot traffic (photo: T.J. Serensits)

9. Core aerator (hollow tine cultivation) used on athletic fields (photo, L. Yoder)

from ⅛ to 1 inch in diameter and 3–8 inches in length (Figure 9). To select the appropriate tine size and spacing configuration, determine the percentage of the field to be affected by the coring procedure. For example, aeration with ¾-inch tines more than doubles the percentage of the field impacted compared to a ½-inch tine. The effects of different tine size and spacing configurations are outlined in Table 2.

Intensively used fields should be core aerated three or four times a year, and fields for seasonal play should be aerated at least twice a year (after the last game, and in the spring). Core-aerate the field in at least two directions. On sand-based fields, allow the plugs to dry and collect them with a core harvester or commercially available vacuum unit such as the one pictured in Figure 7. Removing these cores, which contain both tillers and thatch, will prevent buildup of organic material in the sand profile. On soil-based fields, allow the plugs to dry and pulverize with a steel drag mat to reincorporate them into the holes created by the aerator. Often, sand topdressing is applied following coring on soil-based fields to improve physical properties and mineralize thatch. In these instances, let the cores dry and remove them from the playing surface with a core harvester or vacuum unit. Research has also found that application of compost following aerification on soil-based fields improves playing quality as well.

Core aeration should be done when soil moisture allows for the hollow coring tines to easily penetrate into the soil profile. However, coring in excessively moist soils can damage soil structure. If the hollow coring tines continually clog during operation, soil moisture is likely excessive.

Following aerification (and subsequent topdressing or reincorporation), irrigate and apply 1 pound of soluble ("quick-release") nitrogen fertilizer per 1000 square feet to encourage rapid recovery. If the entire field cannot be aerated, concentrate on the most heavily used areas.

Do not confuse core aeration with solid-tine aeration or spiking. The practices involve poking small holes in the uppermost layers of the soil surface to promote gas exchange and infiltration of water. Solid-tine aeration and spiking are not substitutes for core aeration. Many commercially distributed hollow-tine aerators can easily be reconfigured for solid-tine aeration. Also, many reel mowers have spiking attachments that are relatively easy to use (Figure 10).

10. Spiking attachment for a power-driven reel mower (photo, A.S. McNitt)

Gypsum is sometimes recommended to improve soil structure. Gypsum is effective only on soils high in sodium (Na) content; it has no effect on soils with low or normal sodium levels. When gypsum is used to solve a problem of excess sodium, it is most effective when tilled into the soil. Surface applications of gypsum have limited value.

Wetting agents in liquid or granular form are sold under a variety of trade names. Their main use is to improve water infiltration into the soil surface. They do

11. Topdressing with sand following aeration

12. Layering in an athletic field rootzone

not reduce soil compaction or increase pore space, but they may occasionally aid in alleviating localized dry spots.

Topdressing

Topdressing is the addition of a thin layer of material to the turf surface. In most instances, this material is sand. Topdressing with sand controls thatch, levels low spots, fills holes, and can be used following coring to improve soil physical properties (Figure 11). On sand-based fields, select a sand that is similar in size to that which predominates the rootzone mix in order to prevent layering (Figure 12). On soil-based fields, select a uniform coarse sand (80% of particles between 1.0 and 0.5 mm and 90% between 2.0 and 0.5 mm) to maximize the amount of large pore space in the rootzone. Following aerification, it is recommended that enough sand be applied to fill the holes created by the aerator and leave a thin layer on the soil surface. Table 2 lists volumes required to obtain specific levels of sand topdressing.

When topdressing as part of a general maintenance program (i.e., not after aeration), light, frequent topdressing applications to build up low areas are preferred over less frequent, heavier applications (> ¼ inch).

Composts can be applied as a topdressing as well. Research has found topdressing soil-based fields with ⅛ inch of compost following aeration to improve athletic field playing quality.

Pest management

Weeds

Weeds are commonly found on poorly managed athletic fields. Reductions in turfgrass density and vigor following foot traffic can open voids (bare spots) in the turfgrass canopy for weeds to germinate. Maximizing turfgrass density will reduce the susceptibility for weed invasion.

Weeds are classified either as grasses (e.g., goosegrass, crabgrass), broadleaves (e.g., spurge, pennywort), or sedges (e.g., purple nutsedge, kyllinga). Herbicides to control these weeds can be either preemergent (applied before weed seed germination) or postemergent (applied to growing weeds).

In Hawai‘i, weeds are present year-round and are not as seasonal as on the U.S. mainland. Many turf managers in Hawai‘i rely heavily on a program of postemergence weed control for bermudagrass athletic fields. Preemergence herbicides such as Ronstar® are used to prevent weed seed germination following aggressive vertical mowing or aeration, as these practices create voids for invasion in the turf canopy. Ronstar does not adversely affect bermudagrass rooting like other preemergence herbicides.

Coarse-textured (wide-bladed) grassy weeds commonly found on athletic fields in Hawai‘i include crabgrass (*Digitaria* spp), goosegrass (*Eleusine indica*),

13. Purple nutsedge (*Cyperus rotundus*)

14. White kyllinga (*Kyllinga nemoralis*)

dallisgrass (*Paspalum dilatatum*), hilograss (*Paspalum conjugatum*), and St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze). While these weeds can be controlled in bermudagrass using postemergence herbicides containing methyl arsenate (MSMA, DSMA, and CMA), it should be noted that the Environmental Protection Agency preliminarily decided, in 2006, to deny these active ingredients re-registration. The official ruling on the fate of methyl arsenate herbicides has not been rendered, but it is likely that they will go off the market in the near future.

Alternative chemicals can be used to control certain weeds on bermudagrass athletic fields. For example, applications of Revolver® (foramsulfuron) provide postemergent control of goosegrass in bermudagrass turf. Including a nonionic surfactant in the spray mixture has been reported to improve the efficacy of Revolver applications; note that two applications of Revolver are needed to provide adequate control of goosegrass in bermudagrass turf in Hawai‘i.

Purple nutsedge (*Cyperus rotundus*) (Figure 13), green and white kyllinga (*Kyllinga brevifolia*, *Kyllinga nemoralis*) (Figure 14), and sandbur (*Cenchrus longispinus* [Hack.] Fern) in bermudagrass may be controlled with Image® (imazaquin) alone or in combination with MSMA. A nonionic surfactant is required for Image applications. SedgeHammer® (halosulfuron) also provides good control of purple nutsedge. Other products such as Certainty® (sulfusulfuron) and Monument® (trifloxysulfuron-sodium) may be used to control sedges and kyllinga on bermudagrass athletic fields. Reapplications approximately every three months may be necessary. (See CTAHR publication L-9, *Nutgrass control in the lawn, landscape, and garden*.)

Broadleaf weeds can be controlled using herbicide products containing combinations of 2,4-D, MCPP, MCPA, or dicamba. These products are marketed under several trade names. Confront® (triclopyr + clopyralid) and a newer product, SpeedZone® Southern (carfentrazone, 2,4-D, MCPP, and dicamba) can be used to control broadleaf weeds, wide-bladed grasses, and sedges in bermudagrass as well.

Herbicides should be applied to actively growing bermudagrass that is not under heat or drought stress; otherwise, phytotoxic injury may be observed following application. To effectively control certain weed species, multiple herbicide applications may be required.

Insects and mites

Monitoring

It is important to accurately identify insects found on athletic fields. Insects harmful to bermudagrass are classified as root-feeding, shoot-feeding, or burrowing. Ex-

Table 2. Amount of sand required and area impacted for various coring and topdressing programs*

Core spacing (inches)	Holes per ft²	Tine diameter (inches)	Tine depth (inches)	Area removed by each pass (%)	Number of passes with aerifier to impact a given area of the field (% impacted)			Sand needed to fill holes and leave a layer on surface, tons per 1000 ft² per layer of:		
					50	25	10	1/8 inch	1/4 inch	1/2 inch
2	36	1/2	3/8	5.0	10	5	2	1.22 1.76	1.78 2.87	2.89 4.00
		3/4	3/8	11	5	2	1	2.04 4.51	2.60 5.08	3.72 6.19
3	16	1/2	3/8	2.2	22	11	5	0.85 1.34	1.41 1.90	2.53 2.93
		3/4	3/8	5	10	5	2	1.22 2.32	1.78 2.87	2.89 4.00
4	9	1/2	3/8	1.3	40	20	8	0.72 0.99	1.28 1.55	2.40 2.68
		3/4	3/8	3	18	9	4	0.93 1.55	1.49 2.10	2.61 3.22
6	4	1/2	3/8	0.5	90	45	18	0.63 0.75	1.19 1.31	2.31 2.42
		3/4	3/8	1.3	40	20	8	0.72 0.99	1.28 1.55	2.40 2.68
8	2 1/4	1/2	3/8	0.31	161	81	32	0.60 0.68	1.16 1.22	2.28 2.35
		3/4	3/8	0.69	72	36	15	0.65 0.81	1.21 1.36	2.33 2.48

*Assumes that sand weighs 1.45 ton per cubic yard and there is 100% efficiency on subsequent passes with the aerifier.
Table created by Dr. D. Minner, Iowa State University, http://turfgrass.hort.iastate.edu/extension/core.pdf

amples include sod webworms, armyworms, cutworms, and chinch bugs. Insect samples can be identified by the CTAHR Agricultural Diagnostic Service Center via your nearest CTAHR Cooperative Extension Service office.

To detect cutworms, sod webworms, southern chinch bugs, fiery skipper larvae, and billbug adults, use the pyrethrum test. Mix 1 tablespoon of a commercial garden insecticide containing 1–2% pyrethrins in 1 gallon of water. If the insecticide has only 0.5% pyrethrins, use 2 tablespoons. Using a sprinkling can, apply the solution as evenly as possible to 1 square yard of recently mown turf. The insects will be irritated and move to the surface within 10 minutes. Collect and count the number of insect larvae to assess the seriousness of the infestation. Sample several locations across the playing field. If the problem is localized, spot treatment may be suitable.

Treatments

Insecticide registrations and labels change often. Check with the nearest office of the CTAHR Cooperative Extension Service or your agri-chemical supplier for the latest recommendations.

Before applying an insecticide against foliar or thatch-dwelling pests, irrigate the turf well, and treat as soon as

the foliage is dry. Apply the insecticide as specified on the product label, and apply enough to thoroughly wet the canopy down to the soil surface. In general, applications vary from about 2–25 gallons of spray per 1000 square feet for most pests except mites, which may require a greater volume because they hide within the folds of leaf blades. Do not irrigate following insecticide applications, unless or until it is necessary to prevent wilting. This allows the insecticide to remain on the plants for the longest possible time. Do not apply insecticides when temperatures exceed 90°F.

In general, liquid sprays work best for treating foliar turfgrass pests, but granular formulations are acceptable for controlling billbugs, cutworms, skipper larvae, and sod webworms. Granules are good for controlling pests residing in or below a thatch layer, because they move past leaf blades and partially penetrate the thatch layer.

Armyworms and sod webworms are the most serious problems on bermudagrass athletic fields in Hawai'i. Insect problems are encouraged by lush growth, mowing at irregular intervals, and allowing thatch build-up. Watch for browning areas and grass blades with a chewed appearance.

Rhodesgrass scale has been the most troublesome scale insect on bermudagrass in Hawai'i. It is usually found near the base of the plant. This spherical insect is up to $\frac{1}{8}$ inch in diameter, has piercing-sucking mouthparts, and is covered with a white, cottony secretion. This white secretion is often visible on the turfgrass foliage in damaged areas. The adult scale lays eggs within its secreted covering. After hatching, the crawlers spread throughout the grass before settling down to feed. The life cycle is about 6–8 weeks. Infested grass turns yellow, and the turf thins and may be killed if the pest is not controlled (Figure 15). Applications of insecticides containing imidacloprid and bifenthrin have been observed to provide control in Hawai'i.

Bermudagrass mite is sometimes a serious pest. Its damage is most severe on common bermudagrass. These yellowish-white, somewhat worm-like mites are extremely small, only about $\frac{1}{30}$ inch long. A microscope or strong hand-lens is needed to find them on infested grass. Mites multiply rapidly and require only about seven days to complete their life cycle. Because this pest is so small and hides beneath the leaf sheath, it is identified primarily by damage symptoms. Leaf blades turn light green and cut abnormally. The internodes shorten, the tissues swell, and the grass becomes tufted so that small clumps are noticeable. The turf loses vigor, thins, and may be killed. Injury is more pronounced during dry weather, especially when the grass is stressed due to poor maintenance.

15. Turf infested with rhodesgrass scale.

For more information on controlling insects in bermudagrass, see CTAHR publication IP-5, Destructive turf caterpillars in Hawaii.

Diseases

Plant diseases are rarely a problem on bermudagrass athletic fields in Hawai'i. If disease symptoms are suspected, contact the CTAHR Agricultural Diagnostic Service Center via your nearest CTAHR Cooperative Extension Service office.

Limiting playing field use

A well established and maintained turfgrass athletic field can withstand significant use without serious damage. However, no athletic field can withstand unlimited use. Over-use will result in damage that cannot be overcome by even the best maintenance program. For example, if a single field is subjected to football practice, soccer practice, band practice, official games, practices for other sports, intramural games, physical education classes, and other activities, the extensive foot traffic will render the task of maintaining quality turf impossible. Furthermore, use of fields during inclement weather can result in damage that requires substantial renovations. Coaches and administrators must take an active interest in scheduling activities to prevent over-use.

Ideally, two or more practice fields should be provided for each main game field. Practice fields should be marked according to official regulations, reducing the need to practice on the game field. Many athletic programs lack the resources to provide these additional practice areas. Priorities for use of the field must be established and adhered to. Activities during the off-season should be limited, especially during the summer and wet seasons.

Maintenance of skinned (non-grass) areas

Skinned (non-grass) areas are common on baseball and softball fields. These specialized areas require very specific maintenance. A CTAHR publication titled "Managing skinned areas on baseball and softball fields" will be released in 2008. Until then, refer to ASTM specification F-2107, *Standard Guide for Construction and Maintenance of Skinned Areas on Baseball and Softball Fields* for information on skinned surface maintenance.

Resources available to sports turf managers

CTAHR publications

Adaptation of turfgrasses in Hawaii. Turf Management, TM-4.

Bermudagrass. TM-5.

Nutgrass control in the lawn, landscape, and garden. Landscape, L-9

CTAHR publications can be obtained from the website www.ctahr.hawaii.edu/freepubs.

Magazines and websites

Trade magazines are an excellent way to learn about the latest technology in the field and to learn about products. Several magazines provide free subscriptions to qualified athletic field managers. Most are available online. Some examples are

SportsTurf. M2MEDIA360, Green Media, 760 Market St. #432, San Fransisco, CA 94102. www.greenmediaonline.com/verticalhome/sportsturf.asp

Athletic turf news. www.athleticturf.net/athleticturf

Sport Notes. http://buckeyeturf.osu.edu

Sports Turf Managers Association. www.stma.org

Professional associations for sports-turf managers

Sports Turf Managers Association, 805 New Hampshire, St. E, Lawrence, KS 66044, STMAinfo@stma.org

Books of potential interest

ASTM International. 2007. Annual book of ASTM standards. Vol. 15.07. End use products. Standard guide for maintaining warm season turfgrasses on athletic fields. ASTM F-2269. ASTM, West Conshohocken, PA.

McCarty, L.B, and G. Miller. 2002. Managing bermudagrass turf. Sleeping Bear Press. Chelsea, MI.

Puhalla, J., J. Krans, and M. Goatley. 1999. Sports fields: A manual for design, construction, and maintenance. Wiley & Sons, Inc. Hoboken, NJ.

Puhalla, J, J. Krans, and M. Goatley. 2003. Baseball and softball fields: Design, construction, renovation, and maintenance. Wiley & Sons, Inc. Hoboken, NJ.

Acknowledgment

The authors thank J.A. Borger, P. Curtis, A.S. McNitt, and T.J. Serensits of Penn State University and L. Yoder of the San Diego Padres for allowing use of their photos. All other photos by J.T. Brosnan.