PEST MANAGEMENT STRATEGIC PLAN
for
TURFGRASS
in the
SOUTHERN UNITED STATES

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Executive Summary

Due to the diverse nature of turfgrass uses, the degree to which pests of this commodity must be managed will vary. Turfgrass putting greens have an extremely low tolerance for damage from pests and will therefore require more extensive management; whereas turfgrass in a recreational park setting can tolerate significantly higher damage from populations of many types of pests and will most likely require lower management inputs. Sod grown in the southern U.S. also has a low tolerance for pests for obvious marketability reasons as well as for regulatory issues related to movement of turf across state and national boundaries.

This Pest Management Strategic Plan will provide an overview of the major insect, mite, disease, nematode and weed pests which affect turfgrass in the southern U.S. Many of the pests described here may be common to turfgrasses throughout the Southern Region, while others are either localized or specific to certain species of grass. But, factors such as potential pesticide exposure, pest pressure and economic and aesthetic thresholds must be examined for each turfgrass and pest scenario. For this reason, pest managers, when dealing with their unique turfgrass situation, should consult with an expert when applying any of the pest management options given here. This report includes information relevant for EPA Regions IV and VI.

Turfgrass in the Southern U.S.

Turfgrass is the most widely grown ornamental crop in the southern U.S. When golf courses, sports complexes, park and recreation fields, sod production, commercial and homeowner lawn care, as well as turfgrass support industries (ex. equipment, seed and personnel) are all taken into account the estimated economic impact due to turfgrass is already a $40 billion dollar industry, according to the the National Turfgrass Research Initiative developed by the U.S. Department of Agriculture in 2003. Turfgrass, therefore, has a tremendous economic impact. Additionally, the Green Industry, which includes the growing and maintenance of all turfgrasses and ornamental plants, is the fastest growing sector in most states. In urban areas turfgrass covers many thousands of acres and will likely increase as urban sprawl continues to expand into agricultural and forested land.

According to the National Agricultural Statistics Service 1998 Census of Horticultural Specialties, EPA regions IV and VI (which includes GA, NC, FL, TX, SC, TN, AL, MS, OK, KY, AR, LA, and NM) accounted for nearly 57% of the acres in turf production in the U.S. for a total of 185 million acres and 45% of total turf sales with a value of $373 million. Turfgrass, sod sprigs or plugs are in the top five horticultural sales in the Southern Region by commodity, accounting for 7.9% of all horticultural commodity sales and a value of $83.7 million. These figures do not account, however for the value of aesthetic and recreational turf acreage.

Turfgrass and sod provide good cover and stability to soil in the landscape. It is important in preventing soil erosion, improving soil organic matter and enhancing soil microbial populations as well as contributing better air quality and to the aesthetics of a landscape. However, turfgrass is prone to large pest pressure in the southern U.S. due to climatic conditions and the perennial nature of the system. Both cool-season and warm-season turf species can be successfully grown in the Southern Region. However, heat tolerance of cool-season species and cold tolerance of warm-season species is an issue for turf managers in some of these areas.

Rising chemical costs, limited availability of long-term residual pesticides, increased pest resistance to pesticides and environmental concerns have emphasized the importance of efficient

turf management and reduced dependency on pesticides. Research has shown that properly maintained turf is better able to ward off certain diseases and weeds and will tolerate a higher number of insects and mites. In addition, rate of recovery from injury, whether pest- or non-pest related, is usually faster when the turf is maintained under proper management practices. Application of alternative pest management options and optimum growing practices, such as those presented in this strategic plan could significantly reduce pesticide risks and economic impacts due to pest damage.

Turfgrass Pest Management Strategic Plan Process

A draft version of this document was prepared at a strategic planning workshop conducted October 21-22, 2004, in Griffin, GA. Invitees (Appendix E) represented turf experts from multiple universities and disciplines belonging to EPA Regions IV and VI. During the workshop the group was divided into Entomology, Plant Pathology and Weed Science sub-groups. The sub-groups first developed efficacy tables for pesticides used in their respective disciplines. To adequately represent the pest management situation in these Southern Regions, the groups then created pest-by-pest profiles based on the efficacy tables. Critical research, education, and regulatory needs for each discipline and overarching needs spanning disciplines, which are summarized on page 5, were then identified. This is the final version of that document.

The majority of information on production and management practices were taken from the Turfgrass Crop Profiles developed in Georgia (Sod), Louisiana, North Carolina and Rhode Island (Sod).

Critical Overall Needs and Priorities for Turfgrass Pest Management

Research

- More information related to the basic biology and ecology of turfgrass pests.
- Better integration of pest management among disciplines.
- Pest and pesticide resistance management (including genomics).
- Better integration of social sciences into turfgrass use, maintenance, etc.

Education

- Increased funding for educational efforts is required as funds for education in all areas is declining and a larger user group needs to be served.
- Researchers in the turfgrass commodity needs better access to agricultural grant programs due to the rapid expansion of the urban sector.
- Development of additional distance education opportunities.
- Better coordination among the disciplines in educational programs.
- Better service for traditionally underserved audiences including non-English speaking audiences and youth education.

Regulatory

- More thorough inspection for certification of transported turfgrass materials is required.
- Enforcement of existing regulations and quarantines.
- Provide increased training opportunities and require higher educational standards for commodity inspectors.
- Increase numbers of well-trained inspectors.
- Consider reclassification of sod production to permit greater access to agricultural pesticide products.

Turfgrass Worker Activities

Residential Lawn and Commercial Turf Care
(Includes church grounds, cemeteries and schools)

IRRIGATION:

- Irrigation is a critical component for maintaining high quality turfgrass and is most common in commercial properties, but becoming increasingly popular in home lawn settings. Few churches or schools will have irrigation on the turfgrass areas. Many irrigation units are automated, "pop up" types that require no worker activity on the turfgrass site unless there is a maintenance problem with the irrigation unit.
- Irrigation is commonly used during the spring, summer and fall and often occurs in close association with pesticide applications. In some instances irrigation may be used immediately after pesticide application to move the product into the soil to the target pest, enhance the pesticide's activity, or to simply remove it from the foliage and thatch..
- Prolonged reentry intervals (REIs) would impact irrigation only in situations that require the installation of irrigation heads in the turfgrass areas or the movement and placement of temporary irrigation units.

FERTILIZATION:

- Fertilization is a common practice in the maintenance of quality turfgrass for residential and commercial landescapes. The application of fertilizers is often done during the same time of year that pesticides are applied. Some products (particularly insecticides and herbicides) may be applied to a fertilizer carrier so the applicator applies both the fertilizer and the pesticide in one application.

MOWING:

- Mowing is done on a frequent basis at the same time of year as pesticide and fertilizer applications. Mowing of commercial properties is often accomplished with larger mowing units that allow the worker to ride, but on other properties (such as home lawn) a walk-behind unit is often used.
- Mowing is typically recommended before pesticide applications to reduce the amount of foliage to which pesticides might bind, thereby further reducing potential pesticide exposure of workers.
- Prolonged REIs might influence mowing schedules, but applications could be timed to avoid any problems. Mowing may occur as often as every 5 days during optimal growing conditions, but few pesticides have an REI longer than 24 hours in turfgrass.

AERIFICATION:

- Aerification is a cultural practice that is applied during periods of peak turfgrass growth and is temporally associated with pesticide application. This is a mechanical process that typically involves riding on or walking behind the equipment. On occasion cores are removed and collected, usually by machine, but cleanup is often by hand with shovels and rakes.

RESEEDING AND OVERSEEDING:

- These practices often take place in the spring and fall (often in conjunction with aerification) and would more commonly be in association with herbicide applications. Workers activities would be limited to walking across the turfgrass or riding on the application equipment.

MOWING:

- Essential for maintenance of dense and uniform playing surface.
- Conducted at frequencies ranging from 1 to 7 times per week (some greens are mowed twice daily), depending on site use.
- Mowing involves little contact with treated turfgrass foliage, as most is performed with riding mowers. Golf course tees and putting greens are often mowed with walk-behind mowers, increasing the chance of exposure through foot contact with treated surfaces.
- When leaf clippings are removed during mowing, handling and emptying of clipping baskets may expose workers to pesticide residues through skin contact.

IRRIGATION:

- Essential for maintenance of turfgrass stands during periods of inadequate rainfall.
- Conducted at frequencies up to several times a day, depending on turfgrass species, use of the turf, weather conditions and the time of year.
- Most irrigation is conducted using automatic sprinkler systems and involves no worker contact with treated surfaces.
- Golf course putting greens are often watered by hand, using a high-output hose and nozzle. There is potential for worker exposure through foot contact with treated surfaces and handling of hose which contacts treated surfaces.

FERTILIZATION:

- Applications of essential plant nutrients are performed as granular applications or frequent foliar sprays.
- Frequency of fertilizer application ranges from annual to biweekly depending on turfgrass species, formulation and site use. Most fertilization is performed with riding tractors and involves no contact with treated surfaces. Granular fertilizers are typically applied to golf course tees and putting greens once or twice per year using a walk-behind spreader, creating the possibility for exposure through foot contact with treated surfaces. A foliar applied fertilizer will be sprayed on these areas often weekly or injected through the irrigation system, but with little potential contact to the applicator.

CULTIVATION:

- Necessary for relief of soil compaction and reduction of thatch accumulations.
- Performed 1 to 5 times per year, depending on turfgrass species and site use by using a variety of aerification implements.
- Aerification plugs and debris are removed mechanically, as a result, there is little opportunity for worker exposure to pesticide residues on foliage or in soil.

Sports Turf
(Includes golf course and athletic field maintenance)

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Sod Production

Environmental conditions, grass type and management may dictate productivity, with a range of 1 to 3 sod harvests per year and 2 to 5 sprig harvests possible per year from the same field. Management options for sod include: a) use of native soils vs. soilless organic mediums; b) sod vs. sprigs or both; c) choice of markets (golf courses, sports fields, residential and commercial lawns and landscaping, roadside and municipal properties) and d) whether to grow certified or non-certified turfgrass. Worker exposure is discussed within the respective activities of sod production and installation.

PLANTING

- Planting of turfgrass on sod farms is typically done either by seed or by vegetative means which include sprigging, plugging, or sodding. Herbicides are often used at planting.
- Irrigation requirements are high during the early establishment phase on sod farms. Therefore, farm workers will be in the fields working with irrigation soon after planting of seed or vegetative means.

- Prolonged REIs could impact irrigation where there is a problem with the irrigation system. If no problems exist, the irrigation systems would work fine as they are highly automated.
- Some sod growers are using soilless medium technology, which relies on an impervious plastic layer that prevents root penetration. Roots grow laterally and produce a uniform product with 100 % of the roots harvested. Problems with nematodes, native soil microflora, weeds and other on-site contaminants may be minimized. Organic and sand-based mediums are used for sprig establishment. Frequent irrigation and fertilization is required. This technology lends itself to international shipment because biotic concerns of sod grown in native soils are minimized.

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FERTILIZATION:

- Turfgrasses on sod farms are routinely fertilized by workers. However, all fertilization is done by mechanical means, which includes tractors equipped with high flotation tires with spreader equipment mounted on to the rear away from exposure.
- Fertilization of turf on sod farms is almost always applied as a dry material that must be watered to activate.

MOWING:

- Turfgrasses on sod farms are routinely mowed during and after establishment. Mowing is always accomplished by tractor-mounted mowers and is never accomplished by walk mowing. Therefore, worker contact with turfgrass tissue during the mowing process is minimal.

HARVESTING SOD:

- Harvesting (or cutting) sod can be very labor intensive. Often, this requires that multiple workers are placed on and around a mechanical sod harvester. As the sod is mechanically cut, it is delivered via conveyor in small sections to palates where the sod is physically

stacked to be loaded onto trucks. Workers physically handle both turfgrass tissue as well as soil. If pesticides are present, the highest level of exposure would occur during this process. Another method of harvest that is gaining momentum is to harvest the sod in various sized sod rolls. Here the sod is cut and rolled mechanically and either dropped for mechanical pickup or the smaller rolls are mechanically stacked on pallets to be loaded on the truck. By this method there is little opportunity for worker exposure to the leaf tissue or the soil.

INSTALLING SOD AT THE CONSUMER SITE:

- Once the turfgrass is harvested, it is hauled on pallets to the installation site. The small sections of turf are placed end-to-end and side-by-side by workers to cover the whole lawn, park or other turf area. The potential for worker exposure is high during installation of these small sections of sod. Alternatively, with the rolled sod, the grass is mechanically unrolled over the soil, and workers only need to align the strips next to each other. By this method of installation, worker exposure is greatly reduced over the small section installation.

Turfgrass Production and Management Issues

Turfgrass management and sod production practices vary across the Southern Region and with grass species or cultivars grown. Pests include diseases, insects, mites, nematodes and, weeds. Some pests will always be present. However, what can be considered an acceptable level of pest activity will vary with each turf use and site depending upon its use and management level. Measures available to the turfgrass manager for the prevention and control of pest problems include the judiciale use of pesticides along with other management practices that promote a healthy, dense, and vigorous turf. Effective insect, mite, nematode, disease or weed management requires familiarization with the symptoms they cause, identification and an understanding of the biology and behavior of the organisms involved.

Accurate identification of the pest or other cause of the problem is necessary to correct the flaw and prevent further damage. Integrated pest management strategies dictate using the most safe, effective and economical control measures available. Pesticides should be considered as only one option among the available biological, cultural, chemical, manual and mechanical pest control tools. If pesticide use is warranted to maintain an acceptable turfgrass quality, the proper selection and use according to the pesticide label is required.

Although fewer pesticides are required during sod production than for some of the other segments of the turfgrass industry, certain pests remain quite problematic and are discussed here. Pesticide use in sod production parallels that in the lawn care industry and other segments of agriculture with herbicide use being most extensive followed by insecticide and then fungicide applications.

Site Selection and Preparation

Proper site selection and preparation can help prevent the development of future problems and is critical for the sod producer. Good soil and surface drainage can help reduce disease and weed problems. Soil mixtures developed specifically for certain types of turf areas can aid the drainage, reduce soil compaction, and provide an environment favorable for good turfgrass growth. Turf cultivars can be selected for their shade tolerance under trees, or selective tree removal can limit shade and tree root competition as well as reduce environmental conditions that favor pest development. Certain diseases such as Pythium are more likely to occur where air movement is impeded by trees or dense undergrowth. Soil amendments to improve drainage as well as fertilizer and lime are best incorporated prior to seeding. The type and quantity of amendments should be determined from chemical and physical soil tests. Soil test results are only as good as the sample submitted. Care should be taken to insure that each sample is representative of each site. Amendments should be evenly spread and thoroughly incorporated to be most effective and to eliminate a future non-uniform appearance of the turf.

For sod production, frequency and duration of cold temperatures, soil type and availability of water are major factors in influencing cost-effectiveness of the operation. Maximum numbers of harvests are achieved in locations with minimal freezing temperatures. Sands, loamy sands, and loam-type native soils are preferred over the heavier clay soils that are characteristic of many areas in the Southern Regions, such as Georgia and Alabama and Texas, because harvesting for sod or sprigs is easier in these soils. Rocky soils and uneven areas are avoided because of harvesting problems and sod uniformity requirements. Soil preparation prior to planting includes fumigation and selecting a site devoid of other grasses and perennial

broadleaf weeds for production of certified grass. Tillage at a proper depth prior to establishment (4-12 in.) promotes rapid rooting and rhizome development and aids in providing a level surface to facilitate harvesting.

Turfgrass Selection

Turfgrass selection should be based on the existing environment, intended use, and expected management intensity and to some degree, the present market conditions. Check with a turfgrass specialist or extension agent to find out which grass cultivars perform best in a given area. Blends and mixtures often perform better than a single variety of cool-season grass when they are available. Cool-season grasses (bentgrass, bluegrass, fescue and ryegrass) are best established during the fall, whereas the warm-season grasses (bahiagrass, bermudagrass, centipedegrass, seashore paspalum, St. Augustinegrass and zoysiagrass,) are best planted in late spring or early summer. Use of improved, well adapted, turf-type grasses, free of objectionable weeds, diseases or insects is one of the best means of preventing pest activity. Numerous cultivars have been released with improved tolerance to certain diseases (such as leaf spot, rust, dollar spot), resistance or tolerance to insects (chinch bugs, billbugs, armyworms and sod webworms) and eriophyid mites (bermudagrass mite and zoysiagrass mite). Insist on certified sod, sprigs or seed to assure plants of high genetic purity. Uncertified plant materials frequently produce turf of low quality that requires more management inputs. By insisting on certified or foundation planting stock or seed, the presence of both grassy and broad-leaf weeds will be reduced.

Nutrition

Fertilizer programs should meet the nutritional needs of the turf without promoting excessive growth. The level of pest susceptibility of a turfgrass can be significantly impacted by improper fertilization. Specific nutrient needs can be determined with a representative soil test. Soils in intensively managed areas should be sampled each year, and less intensively managed areas should be sampled every 2 to 3 years. In addition to soil sampling, nutrient analysis of tissue can be done as a more precise gauge of fertility requirements on intensively managed turfgrass areas. Avoid fertilizing cool-season grasses with high rates of nitrogen in late spring and summer to prevent injury from environmental stress and pests. Such grasses are best fertilized during the cooler portions of the year, especially the fall.

Fertilization of warm-season grasses during late spring/early summer encourages healthy dense turf that can withstand weed encroachment. Warm-season grasses may benefit from potassium applied in late summer to help improve winter hardiness. Care should be taken when using quick-release sources of nitrogen to prevent turfgrass injury (leaf burn) and promotion of lush, succulent growth. Use of slow-release nitrogen sources can limit burn and excessive growth, but should be timed to preceed the optimum growth period of the grass species. Some sod producers often apply soluble fertilizers rather than slow-release fertilizers because they help to reduce costs of production.

Irrigation

Irrigation can be of great benefit and is often a necessity upon seedling grass establishment. When irrigating, water should be applied longer and infrequently to allow for deeper penetration into the root zone. Foot printing, leaf curling and discoloration of the turf surface are indications that turf needs to be watered. Light, frequent watering encourages a shallow root system, compaction from traffic and higher susceptibility to pests and environmental stresses. Deep, infrequent watering encourages plants to develop an extensive root system. Irrigation schedules should attempt to minimize the time during which foliage remains moist to discourage disease. Early morning applications have proven to be the most effective and efficient time to water. Localized dry spots on golf greens are best controlled by coring and hand watering or by applications of wetting agents on the isolated dry areas.

When alternative water sources (gray water) are used, especially those with salts, heavy metals or bicarbonates, management must include frequent irrigation applications to move the salts through the soil profile. Periodic applications of gypsum help to minimize salt layering from excess bicarbonates or zonal accumulation.

Mowing

Mowing frequency and cutting height are important for maintaining quality turf, and must be adjusted to the time of year and growth rate of the grass. As a general rule no more than 30 to 40 percent of the leaf area should be removed in any one clipping. Scalping and puffiness are often indications that the turf is not being maintained at the proper height of cut. In general, raising the cutting height helps grasses withstand environmental stress, provided an effective cutting height is maintained. Some golf course superintendents, for example, raise the cutting height of bentgrass slightly on greens to minimize the effects of midsummer stress. Mowing height and frequency for sod production varies greatly with grass species and cultivar. Mowing grass when it is wet may prevent the clippings from sifting back through the foliage and may spread disease pathogens. Using a sharp blade will provide cleaner cuts of turfgrass leaves, which will improve appearance of the turf and may reduce pathogen infection.

Turf Cultivation

Turfgrass areas may be subjected to heavy traffic, which causes compaction and prevents water and nutrients from entering the soil. Turfs grown in compacted soils are less vigorous and more vulnerable to environmental stress. Wet soils are especially prone to compaction. Turf managers should avoid watering playing fields 1 or 2 days before a scheduled event. Turf cultivation or coring practiced when weather conditions are suitable for active growth of a turf, helps alleviate compaction, accelerates drying of persistently wet soils and improves turfgrass response to nutrients and certain pesticides. Cutting slits (slicing) and punching holes (spiking) in some soils will improve water infiltration and stimulate root growth but other soils may require coring.

Thatch

Thatch can be defined as a layer of dead and living stems and roots situated above the soil surface. Contrary to popular belief, grass clippings are not a component of thatch. In fact, grass clippings, which are 75% to 85% water, decompose quickly and release nutrients that help

to fertilize the turfgrass (grasscycling). Major causes of thatch accumulation include (1) use of vigorous sod forming turfgrasses; (2) overfertilization, especially high rates of nitrogen and (3) frequent misuse of certain fungicides, herbicides and insecticides. Soil aeration (coring) combined with topdressing and verticutting (power raking) has been shown to be an effective means of controlling thatch buildup on intensively managed turfs by increasing the rate of decomposition. A good topdressing mix (one that is compatible with the existing soil) should be applied. Topdressing and vertical mowing are frequently used to reduce thatch buildup on golf course greens and other high maintainence turf areas. On large or less intensively managed areas, reincorporation of soil cores following aeration, using a drag mat, is an acceptable alternative to topdressing. Light, frequent verticutting is preferred when thatch is excessive. The practice of dethatched should be done at a time when the turf can quickly recover. However, overstimulation of plant's growth should be avoided. Slow-release sources of nitrogen are less likely to leach and volatilize.

Key Pest-by-pest Profiles and Critical Issues:
Insects, Mites and Nematodes

Turfgrass and sod managers may encounter numerous arthropod and nematode pests depending on location of and turf type that is maintained or produced. Insect pests in the Southern Region that are most damaging are the subterranean mole crickets or white grubs which damage all species of turfgrass grown in the region and because they are difficult to detect, sample and control. Surface feeding caterpillars (cutworms, sod webworms, striped grass loopers, and especially armyworms) cause annual to occasional serious injury to turfgrasses. The tropical sod webworm is annually devestating to lawns of both bermudagrass and St. Augustinegrass in Florida and Texas. Insects that extract plant fluids from turfgrasses include chinch bugs, spittlebugs and greenbug aphids feeding above ground and ground pearls (mealybugs) insects feeding below ground. The southern chinch bug is specific to St. Augustinegrass and it is the limiting factor for its maintenance and production. Eriophyid mites cause frequent damage to bermudagrass, zoysiagrass and buffalograss. Billbugs are and increasing problem in turf. Although not directly injurious to turfgrass, fire ants pose problems when they interfere with turfgrass management (mowing) and the sale and shipment of sod. They significantly interfere with the utilization of lawn and sports turf because of their aggressive behavior. Plant-parasitic nematodes injure turfgrass roots so that the grass is unable to extract water and nutrients from soil, leading to increased susceptibility to stress and decline of the turf.

Pest Name(s) (common, scientific): White grubs
Masked chafers (*Cyclocephala* spp.), **May or June beetles** (*Phyllophaga* spp.), **green June beetle** (*Cotinis nitida* L.), **Japanese beetle** (*Popillia japonica* Newman)**, sugarcane beetle** [*Euetheola humilis rugiceps* (LeConte)] and **other species** (Scarabaeidae).

Distribution, damage and importance:

- White grubs are the most cosmopolitan and damaging turfgrass pest of cool- and warm-season grasses in the US.
- Feed on grass roots and are transported in sod and nursery plants.
- White grubs are most damaging as third instars.
- Adults of some species may cause tree or shrub defoliation and fruit damage.
- White grubs attract predators such as armadillos, skunks and raccoons and birds which cause collateral damage to the turf.

Chronology:

- Masked chafers, Japanese beetles and green June beetles have one-year life cycles.
- Most June beetles (*Phyllophaga*) have 1- to 2-year life cycles.
- Several species of white grubs in Florida have two generations per year.
- Grub presence in turf varies with species and location, but typically first instars are present in mid summer, second instars later in the summer and third instars from late summer through the following winter and spring.

Control measures used and recommended:

Cultural/mechanical:

- Reduced irrigation and use of sodium vapor lights (instead of mercury vapor bulbs) may reduce the attractiveness of some turf during adult flights.
- Avoid organic fertilizers (ex. poultry litter) during adult flights of green June beetle, Ataenius beetles, and other dung-feeding scarabs.
- Resistant cultivars of turf have not been found for most grass species; however, 'Reveille' hybrid bluegrass and Tejas 1 Texas bluegrass both exhibit good tolerance to *Phyllophaga* spp.
- Endophytic turfgrass may enhance tolerance and recovery.
- Increased irrigation during grub feeding (not adult flights) may enhance turf tolerance to feeding damage.

Biological:

- Natural enemies (e.g. predators, parasitoids, pathogens) may help suppress populations, but none are abundant enough to provide adequate control.
- Insect parasitic nematodes vary in effectiveness.
- *Bacillus popilliae* – the commercial product is only partially to marginally effective against Japanese beetle larvae and not effective against the other grub species.
- Marginal effectiveness has been exhibited by several commercial nematodes.

Chemical:

- Healthy turfgrass can tolerate some root damage by white grubs, but insecticidal control is often necessary.
- Many turfgrass managers have a zero tolerance to damage and will treat if only a few grubs are found.
- In areas with historical grub infestations, preventive treatments of imidacloprid or halofenozide provide excellent control of young grubs. A new product called Arena (a.i. clothianidin) is similar to Merit in efficacy but may not have as long of a residual effect.
- Curative control of older larvae is excellent with trichlorfon for most grub species and good with bifenthrin, chlorpyrifos and carbaryl against green June beetle grubs.
- The number of grubs per square foot or damage threshold varies by grub species, grass species and variety, and management intensity or use.

State/local pesticide restrictions or limitations, export issues, etc.:
Japanese beetle is a regulatory pest.

Critical issues and needs:

- Basic life history of southern grub species, especially in Florida.
- Basic life history of the sugarcane grub as a pest of turfgrass.
- Identification of natural enemy complex and importance.
- Timing and prediction of preventive and curative applications.
- Development of damage and action thresholds in various turf species, management levels and turf production systems.

Chemicals used:
Carbamates: Carbaryl

Diacylhydrazines:	Halofenozide
Neonicotinoids:	Imidacloprid, Chlothianidin, Thiamethoxam
Organophosphates:	Trichlorfon, Chlorpyrifos
Pyrethroids:	Bifenthrin, Cyfluthrin, Deltamethrin, Lambda cyhalothrin

Pest Name(s) (common, scientific): Mole crickets
Short-winged mole cricket (*Scapteriscus abbreviatus* Scudder), **southern mole cricket** (*Scapteriscus borellii* Giglio-Tos) and **tawny mole cricket** (*Scapteriscus vicinus* Scudder).

Distribution, damage and importance:

- Very serious pests of turf and pasture grasses in the coastal plain region of the southeastern U.S. from southeastern NC around to eastern Texas.
- Feed on grass roots or act as a predator. Mole crickets kill turf and disturb soil through their feeding and tunneling activities.
- Predation from birds and small animals often causes extensive collateral damage.
- The pest species are all introduced from South America. The southern and tawny mole crickets are widely distributed throughout the region, due to their ability to fly long distances.
- The short-winged mole cricket cannot fly and is limited in its U.S. distribution to localized populations in Florida.
- Most damage is done in mid-summer through the fall by feeding and tunneling of nymphs, with some additional damage in the spring when large nymphs and adults return to the surface and the adults migrate by flight to new locations to lay eggs. In Florida, the damage is nearly year-round.

Chronology:

- There is one generation of tawny mole crickets per year throughout its U.S. range. The Southern mole cricket also has a single generation per year, except that there is a second generation in the southern part of Florida.
- The short-winged mole cricket has multiple generations and all stages can be found year round.

Control measures used and recommended:

Cultural/mechanical:

- Tolerance to tawny mole cricket has been documented in 'TifSport', 'TifEagle' and 'Ormond' cultivars of bermudagrass.
- 'Diamond', 'Cavalier', 'Palisades' and 'Emerald' zoysiagrass are tolerant to tawny mole cricket.
- Tolerance to southern mole cricket has been identified in 'Tifton-44' bermudagrass, 'Floratam' St. Augustinegrass and 'Excalibur' seashore paspalum.

Biological:

- The entomophagous nematode *Steinernema scapterisci* is available commercially as Nematac-S. This is a specific parasite of *Scapteriscus* spp. mole crickets, and has no effect on any other organisms including the native northern mole cricket, *Neocurtilla hexadactyla* (Perty). Efficacy is generally not as good as with chemical insecticides.

- *Larra bicolor* F., a sphecid wasp, has been introduced into Florida and Georgia and has been found in Mississippi and shows promise for further spread.
- Several species of ground beetles and *Lycosa* spiders feed on younger instar mole crickets.
- Many native birds and mammals also feed on the *Scapteriscus* complex.

Chemical:

- Primary way to reduce damage, which can quickly destroy large areas of turf, is through pesticide application.
- Thresholds vary from none on putting greens to 3 per square yard on fairways and home lawns.
- Mole crickets are difficult and expensive to control. The cost often exceeds $300 per acre.
- Fipornil is a widely used insecticide that has proven to be the most effective and most expensive single application approach. Since it provides season long control the economics must be considered in that context..
- Indoxacarb, acephate, the bifenthrin + imidacloprid combination and chlorpyrifos baits are available for use against larger nymphs in late summer.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Acephate has undergone label changes in recent years and can't be used for mole crickets in home lawns.
- Bifenthrin, cyfluthrin, lambda cyhalothrin and imidacloprid are less effective, particularly on larger nymphs and adults.
- Additional research into resistant turfgrass cultivars could provide cheaper management alternatives. Only limited resistance has been found so far.

Chemicals used:

Neonicitinoids:	Imidacloprid
Organophosphates:	Acephate, Chlorpyrifos (bait)
Oxadiazine:	Indoxacarb (bait)
Phenylpyrazoles:	Fipronil
Pyrethroids:	Bifenthrin, Cyfluthrin, Lambda cyhalothrin

Pest Name(s) (common, scientific): Billbugs
Bluegrass billbug (*Sphenophorus parvulus* Gyllenhal) and **hunting billbug** (*Sphenophorus venatua vestitus* Chittenden).

Distribution, damage and importance:

- Several species of billbugs occur nationally and are pests of both warm- and cool- season turfgrass.
- While a complex of species may occur in any turf setting, two species are most common in the southeastern U.S. The hunting billbug occurs primarily warm-season turfgrasses

(*Buchloe, Cynodon, Stenotaphrum, Zoysia*) and the bluegrass billbug is most common in cool-season turf (*Agrostis, Festuca, Poa, Lolium*).

- Adults cause minor damage but the grubs feed on stems, rhizomes and the crown of the plant.
- The hunting billbug can be a serious problem in home lawns, sod production and golf courses while the bluegrass billbug is typically observed in home lawns and sod production
- Young larvae feed internally in the crown, rhizomes and stolons and older larvae feed on the whole root system. Patches of turf turn yellow, then brown and die. Grass stems stems break near the crown, and frass is visible in the stems. Heavily infested sod falls apart and will not harvest.
- Billbug larvae are legless (white grubs have legs). Infestations may be misdiagnosed as early winter dormancy,slow spring green-up white grubs or any of several disease infections.
- Bermudagrass and zoysiagrass are preferred hosts, but resistant cultivars have been identified.

Chronology:

- Billbug adults are present in the spring after overwintering as large grubs or adults. Depending upon location and billbug species, multiple generations may occur, although two generation per year is common.
- Grubs are typically found throughout the summer and fall.

Control measures used and recommended:

Cultural/mechanical:

- Both cool- and warm-season turfgrass cultivars vary in susceptibility to billbugs.
- Resistance to hunting billbug has been identified in 'Cavalier', 'Diamond', 'Royal' and 'Zorro' zoysiagrass.
- Tolerance to bluegrass billbug has been identified in 'Reveille' hybrid bluegrass and 'Arista', 'Arboretum', 'Nebraska Common', 'Park' and 'South Dakota Certified cultivars of Kentucky bluegrass, although these are not used as commonly as in the past.
- Endophyte enhanced ryegrasses and fescues are less susceptible than non-endophytic cultivars.

Biological:

- Biological control approaches are limited which results in an increased dependency on chemical control methods. Use of biological materials for billbug management has been very limited.
- Parasitic wasps of eggs may help suppress populations as may *Beauveria* fungal pathogens. Commercial products containing *Beauveria bassiana* have been available on an irregular basis.
- Entomogenous nematodes have been evaluated with some level of success in controlled field trials. These products have minimal environmental and under protection concerns, but effectiveness has been questionable. In the case of sod production, cost is always a concern.

- Cultural control approaches are limited and result in an increased dependency on chemical control methods.

Chemical:

- Insecticides are the most common method of control.
- Two options are available for management: adult control and larval control.
- The sporadic occurrence and multiple generation of the pest make its appearance unpredictable and turfgrass managers often respond in a 'secure' mode.
- Some areas that consistently experience billbug injury may be treated in a prophylactic manner.
- No concerns for resistance have been expressed, but repeated application of the same product over a number of years could increase the likelihood of enhanced microbial degradation in the soil.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues and needs:

- The life cycle of various billbug species is not well defined in many areas across the South which can result in poor control due to incorrect timing. Local databases are needed to better understand the basic biology and behavior of the hunting billbug which will help with timing of applications against both adults and larvae.
- An improved description of billbug life history will also increase the likelihood of successfully using biological control methodologies.

Chemicals used:

Carbamates:	Carbaryl
Diacylhydrazides:	Halofenozide
Neonicotinoids:	Imidacloprid, Clothianidin
Organophosphates:	Acephate, Chlorpyrifos, Trichlorfon
Pyrethoids:	Bifenthrin, Cypermethrin, Cyfluthrin, Deltamethrin, Lambda-cyhalothrin, Permethrin

Pest Name(s) (common, scientific): Chinch bugs
Southern chinch bug (*Blissus insularis* Barber)**, hairy chinch bug** (*Blissus leucopterus hirtus* Montandon)**, common chinch bug** [*Blissus leucopterus leucopterus* Say)] and **western chinch bug** [*Blissus occiduus* (Barber)].

Distribution, damage and importance:

- The southern chinch bug is part of a complex of *Blissus* that are difficult to taxonomically separate even under a dissecting microscope.
- The southern chinch bug (SCB) is the most important insect pest of St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze).
- SCB is damaging across the Southern Region of the U.S. from NC and FL to CA and in HI and throughout the Caribbean Archipelago. It is damaging to St. Augustine throughout its region of adaptation.

- Chinch bugs damage grass by sucking the plant juices and injecting a toxin which kills the host grass.
- The common chinch bug is damaging to zoysiagrass and bermudagrass.
- The western chinch bug is a pest of buffalograss.
- Hairy chinch bug feeds on cool-season turfgrasses including tall fescue, Kentucky bluegrass and rygrasses.

Chronology:

- Under conditions from Atlanta to Dallas, chinch bugs pass through 2 generations per year. The number of generations increases increased temperatures. In southern Florida there are 7-10 generations per year with first instars present throughout the year.
- St. Augustinegrass turf is most susceptible once it develops a thatch layer and when it grown under medium to high N fertility or when the fertility is out of balance.

Control measures used and recommended:

Cultural/mechanical:

- A thatch layer is necessary before SCB will establish and build-up.
- Fertility rates also impact SCB populations. A balanced fertility program can induce a level of SCB resistance into a susceptible St. Augustinegrass cultivar.
- The ratio of N-P-K helps with the induced resistance. When N is too high the population of SCB increases. If either P or K is too low the grass is also more susceptible. There is also a difference in SCB susceptibility due to N source (eg water soluble vs. water insoluble).
- Resistant cultivars, 'Floratam' and 'Floralawn', of St. Augustinegrass have been developed. Originally these cultivars had and antibiotic rate of 80-100% kill of confined SCB adults. This resistance has broken down in parts of FL after nearly 20 years of field use. Breeding programs are underway in Texas and Florida to identify additional St. Augustinegrass cultivars with SCB resistance.

Biological:

- A complex of parasites and predators have identified that feed on SCB in Florida. An egg parasite, *Eumicrosoma benefica*, reduces egg numbers significantly in lawns. The stripped earwig, *Labidura repara* (Pallas), can kill up to 50 adult SCB in a 24-hr period. Two big eyed bugs, *Geocorus uliginosis* Say and *G. bullatus* (Say), feed heavily of all nymphal stages of SCB. Several species of Lycosis spiders are also very active predators on SCB.
- *Beauveria bassiana*, a parasitic fungus is often found attacking chinch bugs under lawn conditions.

Chemical:

- Chemical controls are often applied from 2-6 times per year for SCB control.
- SCB exhibits complete cross-resistance to all classes of organophosphate and chlorinated hydrocarbon insecticides and many of the carbamate insecticides.
- Pyrethroids are effective, but they provide no residual control and evidence of resistance has already surfaced for bifenthrin, with cross-resistance to other pyrethroids is expected.

- The high incidence of insecticide resistance in this pest is caused by: a) multiple generations of the pest (up to 10 per year); b) constant exposure of the host-St. Augustinegrass is green throughout the year in central and southern Florida; c) a very active and well developed lawn care industry that relies heavily of this pest for income; d) execssive numbers of treatments per year and a tendency to use half rates when populations are low.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues and needs:

- Clear understanding of the identification and behavior of the *Blissus* spp. complex.
- New classes of insecticides need to be developed that are effective against SCB, especially with the strong indication of SCB resistance to the pyrethroids. **As new insecticide classes are developed, rotation among the classes should be encouraged.**
- Alternatives to chemical control need to be identified and developed.
- The lawn-care industry also should be monitored to insure that they are not using sublethal dosages and also to insure they are only treating to control and not as a preventative.
- Reducing the number of treatments and applying spot treatments (which is most effective especially early in the season) will allow for the conservation of natural enemies, as native parasites and predators can play a significant role in SCB management.

Chemicals used:

Neonicotinoids:	Imidacloprid
Organophosphates:	Acephate (not legal for use on home lawns), Carbamate, Carbaryl
Pyrethroids:	Bifenthrin, Cyfluthrin, Lambda cyhalothrin

Pest Name(s) (common, scientific): Imported fire ants
Red imported fire ant (*Solenopsis invicta* Buren), **black imported fire ant** (*Solenopsis richteri* Forel).

Distribution, damage and importance:

- A major pest of residential and commercial turf throughout the southern region of the U.S. It is continuing to spread and permanently establish throughout the south and its distribution if farther north each year.
- It is a potential health hazard in every component of the turf industry due to its aggressive defense of its mound, and its painful sting. Some people are extremely sensitive to its venom.
- It is a nuisance on residential turf, sports fields and golf courses due to its mound building activities and potential to aggressively sting when disturbed.
- There are regulatory issues in the commercial sod production industry to limit its spread into non-infested areas.
- These ants nest in large, soil mounds (up to 24 in. high) that go deep into the soil. Any mound disturbance causes ants to immediately defend the nest. Stings result in tiny pustules, pain, itching and sometimes an allergic reaction and anaphylactic shock.

Chronology:

- Mound building activities are most noticeable in spring and fall particularly after a 2- to 3-inch rainfall.
- Mating occurs in the spring and early summer.

Control measures used and recommended:

Cultural/mechanical:

- None noted.

Biological:

- Biological control is being utilized to assist in control of red imported fire ant. One agent is a complex of phorid flies (*Pseudacteon* spp.), and another natural enemy is a microsporidian (*Thelohania solenopsae*). These two natural enemies are being released and evaluated for suppression across the infested regions.

Chemical:

- Pesticides are a critical component for managing red imported fire ants. They are used to treat large areas of land (using baits and broadcast insecticides) and for individual mound treatment.
- The most effective method for control seems to be the use of a combination of bait or broadcast insecticide coupled with individual mound treatments. Baits are formulated with slow-acting toxins or growth regulators that are designed to pass among the workers and reproductives as they feed each other. Baits are most effective when soil temperatures warm enough to allow workers to actively forage.
- Broadcast insecticides are formulated to be applied as a granular application or a broadcast spray, with slow- or fast-acting toxins.
- The greatest hazard to applicators and handlers is probably due to mound drench products during the mixing operation. Baits, especially those that contain an insect growth regulator are safer for the applicator.
- Scatter granules around the edge of the nest, not on top, for a mound treatment. Ants take the bait into the colony and feed the treated oils to each other, which results in colony death. Some baits work within 48 hr., some take a month.

State/local pesticide restrictions or limitations, export issues, etc.: Imported fire ants are a regulatory issue.

Critical issues: None noted.

Chemicals used:

Avermectins:	Abamectin
Carbamates:	Carbaryl
Hydramethylnon:	Hydramethylnon
Juvenile hormone analogues:	Fenoxycarb, S-methoprene, Pyriproxyfen
Organophosphates:	Acephate, Chlorpyrofos
Oxadiazine:	Indoxacarb
Pyrethroids:	Bifenthrin, Deltamethrin, Lambda cyhalothrin

Phenylpyrazoles:	Fipronil
Spinosyns:	Spinosad

Pest Name(s) (common, scientific): Lawn caterpillars
Armyworm (*Pseudaletia unpuncta* Haworth), **fall armyworm** (*Spodoptera frugiperda* J.E. Smith), **lawn armyworm** (*Spodoptera mauritia* Boisduval), **black cutworm** (*Agrotis ipsilon* Hufnagel), **granulated cutworm** [*Agrotis subterranean* (Fabricius)], **variegated cutworm** (*Peridroma saucia* Hubner), **tropical sod webworm** (*Herpetogramma phaeopteralis* Guenee), **sod webworms** (*Crambus* spp., *Parapediasia* spp., *Pediasia* spp., and *Fissicrambus* spp.) and **striped grass loopers** (*Mocis* spp.).

Distribution, damage and importance:

- Armyworms, cutworms and sod webworms occur all across the southern regions. In most cases, the late instar lawn caterpillars, because they are much larger, consume much more food and are thus more damaging.
- The armyworm moths lay their egg masses in turfgrass and cereal crops while the fall armyworms also attack many other herbaceous plants. When populations are high and conditions are favorable, large populations of larvae can damage large areas of turfgrass and cause a near complete removal of all green tissue.
- Armyworms feed on all species of turfgrass and are important pests in all turf settings from sod farms and sports fields to landscapes and pastures.
- Cutworms (black, granulate and variegated) are primarily a problem in high quality turf including sod farms and golf courses (especially tees and greens) and high level lawns.
- Even relatively low population levels can cause objectionable damage.
- Sod webworms, primarly the tropical sod webworm, is one of the primary pests of St. Augustinegrass, bermudagrass and bahiagrass. Populations can reach levels as high as 25-30 per square foot and these levels can devastate a turf planting.outbreak in Florida or southern Texas.
- The other sod webworms (silver-striped, bluegrass, larger and striped) are present in turf, but generally not as serious a problem as the tropical sod webworm or the cutworms and armyworms.
- Most sod webworm species do not kill the grass since they do not feed extensively on the crown. Damaged turf generally recovers quickly with proper fertilizer applications and timely irrigations.
- Most sod webworm species do not kill the grass since they do not feed extensively on the crown. Damaged turf generally recovers quickly with proper fertilizer applications and timely irrigations.
- Feeding damage by tropical sod webworm on St. Augustinegrass can damage the crown and kill areas of the turfgrass. St. Augustinegrass that has been severely defoliated is slow to recover.
- Young caterpillars skeletonize grass blades. Older caterpillars may notch the sides or completely eat the grass blades. Damaged grass may look ragged or scalped. In severe infestations, the turf may look like it is moving.

Chronology: Varies depending on type of caterpillar and location.

Control measures used and recommended:

Cultural/mechanical:

- The removal of eggs during daily mowings of golf greens along with the use of a roller will remove many of the eggs.
- Caterpillars tend to become a problem in newly established turf, or in early fall, especially if the turf was fertilized heavily in late summer.
- Over-fertilization with too much Nitrogen can attract populations of fall armyworms, cutworms and sod webworms.

Biological:

- Commercial formulations of *Bacillus thuringiensis* provide control of the lawn caterpillars, especially effective on the tropical sod webworm.
- Parasitic tachinid fly and hymenopterous parasitoids are important natural controls.
- The striped earwig, *Labidura ripara*, ground beetles, big-eyed bugs and *Lycosa* spiders are active predators of the lawn caterpillars.

Chemical:

- Lepidopterous pests are best controlled with insecticides in the early instars when they are still small.
- There are a number of insecticides labeled for control. Most of these insecticides are broad-spectrum and fairly economical, especially chlorpyrifos, acephate, carbaryl and several labeled pyrethroids.
- Newer products such as spinosad and halofenozide are also effective but not as economical as some of the other choices. *Bacillius thuringiensis* insecticides are very specific for lepidoptera and also work best on early instar larvae.
- The use of soap solution or disclosing solution can be made periodically during the spring and summer to monitor for presence of the larvae. Aesthetic thresholds have been developed for some of the lawn caterpillars to aid in control decisions.
- Insecticide resistance is not a major concern in most areas because treatments are only made occasionally and there are many acres of unsprayed grasses to act as refugia.
- With the frequent overlapping generations of the tropical sod webworm, there is concern for insecticidal resistance.
- Treat at the first sign of damage. Reduced-risk products like Dipel, Mach 2, and Conserve are more effective against younger caterpillars.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Information on influence of cultural and biological controls.

Chemicals used:

Biologicals:	*Bacillus thuringiensis*, Dipel
Carbamates:	Carbaryl
Juvenile hormone analogues:	Pyroproxyfen, Fenoxycarb
Neonicotinoids:	Imidacloprid
Organophosphates:	Acephate, Chlorpyrofos, Trichlorfon

Oxadiazine:	Indoxacarb
Phenylpyrazoles:	Fipronil
Pyrethroids:	Bifenthrin, Cypermethrin, Cyfluthrin, Deltamethrin, Lambda cyhalothrin, Permethrin
Spinosyns:	Spinosad, Conserve

Pest Name(s) (common, scientific): Eriophyid mites
Bermudagrass mite (*Eriophyes cynodoniensis* Sayed), **zoysiagrass mite** *(Eriophyes zoysiae* Baker, Kono and O'Neill), **buffalograss mite** [*Eriophyes slykhuisi* (Hall)].

Distribution, damage and importance:

- The three eriophyid mites are very host specific and are present throughout the areas of adaptation of their respective hosts (bermudagrass, zoysiagrass and buffalograss) in the Southern Regions.
- They are typically a problem in hot, sunny turf areas that are experiencing some level of drought stress.
- Under heavy infestations and drought stress, thinning or a complete loss of stand can result.
- The turfgrass takes on a different textured look and may even be discolored.
- Damage from bermudagrass mite and buffalograss mite is expressed as shortened internodes and leaves with an overall tufted or witches-broom appearance.
- Zoysiagrass mite causes a rolling of the leaf with the midvein turning yellow due to the high number of mites feeding inside the leaf roll. Also new leaf tips are twisted and caught in partially unrolled older leaves, resulting terminal arches or "buggy whip" symptoms.

Chronology:

- These eriophyid mites are present on the respective hosts throughout the year.
- They are normally present in very protected feeding sites in rolled leaves on zoysiagrass or under the leaf sheath on bermudagrass and buffalograss.
- Under humid or moist conditions they will migrate from their feeding sites and be present over the whole plant.
- They colonize new turf areas by produce silken threads to balloon from one plant to another and they also hitchhike on other insects.

Control measures used and recommended:

Cultural/mechanical:

- Control of these mites is often attempted through cultural practices, including close mowing or scalping of the turfgrass to remove the infested tissue offsite to be destroyed, aggressive fertilization, and additional irrigation. The intent of these practices is to impact the mite population with the close mowing and to stimulate new turf growth ahead of the developing populations.
- FloraTeX bermudagrass is highly resistant to the bermudagrass mite.

Biological:

- None noted.

Chemical:

- Diazinon was very effective but is no longer available.
- Materials that are labled provide only marginal control.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Screening of germplasm of all three turfgrass species (*Cynodon, Zoysia* and *Buchloe*) to develop resistant cultivars for each turfgrass.
- Understand the basic biology and behavior for all three species of eriophyid mites
- Understand the host-pest relationships that cause the plant deformities on each host species.
- Identification of critical non-chemical or low impact management practices.
- Development and registration of efficacious acaricides.

Chemicals used:

Organochlorine: Dicofol

Pest Name(s) (common, scientific): Two-lined spittlebug (*Prosapia bicincta* Say).

Distribution, damage and importance:

- Two-lined spittlebug (TLS) is an occasionally serious pest of managed turf in the Southeastern U.S.
- Centipedegrass and bermudagrass are the most susceptible grass, although all warm-season grasses are susceptible or may be infested. Both adults and nymphs injure turf.
- Adults feed on turf and some ornamentals, nymphs feed on herbaceous plants, primarily grasses.
- Can be a major concern to turf managers in residential and commercial turf in certain situations.

Chronology:

- There are two generations in the Southeast, with a partial third in some areas.
- A toxin in injected into the plant during feeding which causes the host plant to yellow and die.

Control measures used and recommended:

Cultural/mechanical:

- There is a range of susceptibility among warm-season grasses to TLS.
- Turfgrass cultivars with improved tolerance/resistance to TLS are a management option. Additional work in this area is in progress.
- Modify ornamental plantings to reduce susceptible plants in the landscape.
- Mowing height and thatch management anecdotally affect spittlebug occurrence and damage, but no data are available.

Biological:

- Control opportunities for two-lined spittlebug are primarily in conservation of existing natural enemies. Few reports of bio-contol agents are documented: bird predation, spiders, and a reduviid.
- Research in progress has identified several generalist predators as having potential impact on TLS eggs, nymphs and adults. Tiger beetles (*Megacephala carolina* Carolinae), big eyed bugs (*Geocoris uliginosus* and *G. punctipes*), red imported fire ant (*Solenopsis invicta*), ground beetles (*Harpulus pennsylvanicus*, *Calosoma sayi*) and wolf spiders (*Lycosa* spp.).
- Nymphs within their spittlemass were only successfully attacked by fire ants. Tiger beetles when presented with both TLS adults and fall armyworm larvae showed a slight preference for the larvae.

Chemical:

- Pesticides used to suppress two-lined spittlebugs have historically included chlorpyrifos, acephate and diazinon.
- With their removal from the residential turf arena, very few effective chemical options are available.
- Pyrethroids applied with sufficient volume of water have been effective but not always consistently.
- Neonicotinyl insecticides show promise but are not labeled for this use.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Understand the basic biology, behavior and host association of the pest.
- Effect of cultural factors including irrigation, mowing height, top dressing and dethatching on TLS need to be investigated.
- Populations are not synchronous. What factors affect diapause and adult emergence.
- Elucidation of pest density/injury dynamics.
- What natural enemies are effective and how they can be augmented and/or conserved.
- Chemical control tools are needed for residential turf.
- Additional work identifying resistant cultivars.

Chemicals used:

Organophosphates:	Acephate, Chlorpyrofos
Pyrethroids:	Bifenthrin, Cypermethrin, Cyfluthrin, Deltamethrin, Lambda cyhalothrin, Permethrin

Pest Name(s) (common, scientific): Nematodes [several different nematode species, primarily **sting nematode** (*Belonolaimus* spp.), **stubby-root nematode** *(Trichodorus* spp., *Paratrichodorus* spp.), **lance nematode** (*Hoplolaimus* spp.), **root-knot nematode** (*Meloidogyne* spp.) and **ring nematode** (*Mesocriconema* spp., *Criconema* spp.)].

Distribution, damage and importance: More than 15 genera of nematodes attack warm-season turfgrasses, but sting nematodes are the most important nematodes in the Southern Regions.

Irregularly shaped patches of declining turf due to nematode damage may be hundreds of feet in diameter. Leaves may be yellow or brown from the tip and roots may appear stubby, rotton, or knotted. These tiny, eel-like worms cannot be observed without the aid of a microscope; suspected problems should always be verified by laboratory analysis.

Damage to roots is the most important effect of nematodes on turfgrasses in the Southeast. The roots may be killed or stunted resulting in poor and shallow root systems. The above ground symptoms are slow growth, thinning of the turf, poor response to adequate fertilization and irrigation, rapid wilting during dry weather, and weed invasion. Analysis of nematode populations in soil samples is the only sure way of determining if nematodes are a problem because they cannot be observed with the naked eye and other diseases or nutritional problems may have similar symptoms.

Nematodes are most damaging in light, sandy soils which are low in nutrients and water-holding capacity. Good fertilization and irrigation practices will often reduce the effects of some types of nematodes. Nematodes are fairly immobile in soil and spread is frequently due to movement of soil and planting materials by man or the elements. The type and number of nematodes present in the soil must be determined before nematodes can be identified as a problem

Chronology:

- Nematode activity and reproduction is largely driven by soil temperature and food availability. In many areas of the southern United States soil temperatures remain sufficiently high to support some nematode activity year-round. Generally, nematode populations on turfgrasses peak at times when new root mass is being produced.
- Nematode levels are usually lowest in the spring and increase to the highest levels in fall.
- Population changes are related to soil temperatures in the upper South.
- Early fall is a good time to have soil samples assayed for nematodes.

Control measures used and recommended:

Cultural/mechanical:

- Make sure that the problem is due to nematode injury by taking a representative nematode sample from the affected area and submitting it to a laboratory for analysis. Samples, consisting of 12 to 20 soil cores approximately 3- to 4-inches in depth, should be taken from the edges of affected areas. The sample must not be allowed to dry out or be exposed to extreme heat or direct sunlight, otherwise nematodes will be killed and an accurate count cannot be made.
- Base fertilizer applications on the results of soil nutrient tests.
- Selection of the most tolerant types of grasses and good management practices will help reduce the effects of many nematodes and are the only practical means of control on low maintenance areas.
- Good sanitary practices that discourage the physical movement of nematode infested soil and plants will also help reduce spread.

Biological:

- None noted.

Chemical:

- Nematicides may be needed on highly maintained areas on golf course tees and greens when sting nematode is present. Labeled chemicals are very toxic to humans and animals so label directions should be followed if they are used.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: A lack of efficacious products, especially for home lawns.

Chemicals used:

Organophosphate:	Fenamifos
Fumigant:	1,3-Dichloropropene

Overall Needs for Management of Insect, Mite and Nematode Pests of Turf

Regulatory:

- A better understanding of the movement of turf pests from infested to uninfested areas in plant materials from commercial nurseries and turf farms.
- New insecticide products, especially to address existing and potential resistance to currently registered products.
- There is a grave need for new acaricide products to help manage the eriophyid mites in bermudagrass, zoysiagrass and buffalograss.
- Stronger coordination of APHIS, the state regulatory agencies and the designated plant diagnostic laboratories for detection, identification and management of potential invasive species (e.g. fire ants).

Education:

- The production of turf is the fastest growing agricultural related industry in the South. Continued development of research-based educational programs targeted to homeowners, schools, commercial horticulture industries, government/parks and recreation and extension personnel.
- Education on pesticide stewardship and the reduction of unnecessary pesticide applications through research-based extension programs.
- There are major needs for programs targeted towards pest management education and the funding that can support the development and delivery of those programs.

Research:

- Pest ecology, life history, behavior and host/pest associations of major pests, and all information on minor pests (eriophyid mites, ground pearls), biological control and host plant resistance.
- There are critical gaps in knowledge of pests and their management that are needed for development of extension education pest management programs.
- Support for efficacy trials of lower-risk insecticides/nematicides and bio-rationals to develop safer management systems.
- Impact of insecticides on target, secondary and introduced pests and on beneficial organisms.

Insecticides, Miticides and Nematicides Used

Avermectin

Abamectin (Ascend, Clinch, Varsity [in ornamentals: Avid])

- Efficacy:
    - Results in death or sterility in imported fire ant queens and mortality of many workers
- Resistance issues: None for the bait formulation.
- Residual: 6-18 months.
- IPM issues: As a bait formulation, abamectin has minimal effect on beneficials.
- Other notes: Used as a bait on imported fire ants. Of concern is keeping the bait fresh so the oils do not become rancid.
- REI:12 h
- IRAC Mode of Action: 6

Biological

***Bacillus thuringiensis* (Dipel, Thuricide, Javelin)**

- Efficacy: Moderately effective on caterpillars, requires thorough coverage.
- Resistance issues: No known resistance problems
- IPM issues: Not toxic to non-lepidopterous organisms
- REI: 12 h
- IRAC Mode of Action: 11A1-B2

Carbamate

Carbaryl (Sevin)

- Efficacy:
    - Excellent for green June beetle control, less effective on other species. Good adult beetle control.
    - An effective carbamate against adult billbugs and used as a curative. Heavy use rate required for chinch bugs and lawn caterpillars.
    - No spot application suggested for chinch bugs.
    - Good to Excellent control for armyworms, cutworms and sod webworms.
    - Used as a contact insecticide for imported fire ants.
- Resistance issues: No resistance concerns noted.
- Residual: Short residual.
- IPM issues: Toxic to some beneficials.
- Other notes: Broad-spectrum; ineffective if turfgrass is irrigated or rained on within 24 h after application; old carbamate; heavy use rate; used as a contact insecticide for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action Classification: 1A.

Diacylhydrazine

Halofenozide (Mach 2)

- Efficacy:

    - Effective against most grubs, billbugs and caterpillars.
    - Oriental beetle not as effectively controlled.
    - Effective when targeted against newly hatched billbug larvae.
    - In areas with historical grub infestations, preventive treatments of halofenozide provide excellent control of young grubs.
- Resistance issues: None noted.
- Residual: Long residual (2-4 months).
- Other notes: Preventive insecticide applied during white grub adult flights or egg hatching; watering it in is important; useful on all turf sites; Unique mode of action and reduced mammalian toxicity. Used as a curative for billbugs. Effective for caterpillar control but not as economical as some of the other choices.
- REI: 12 h.
- IRAC Mode of Action Classification: 18.

Juvenile hormone analogue (Insect growth regulator)

Fenoxycarb (**Logic, Award)**

- Resistance issues: None noted.
- Residual: 6-18 months.
- IPM issues: None noted.
- Other notes: Used as a bait for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action: 7B.

S-methoprene (Extinguish)

- Resistance issues: None noted.
- Residual: 6-18 months.
- IPM issues: None noted.
- Other notes: Used as a bait for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action: 7A.

Pyriproxyfen (Distance, Esteem, Spectracide)

- Resistance issues: None noted.
- Residual: 6-18 months.
- IPM issues: None noted.
- Other notes: Used as a bait for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action: 7C.

Metabolic inhibitor

Hydramethylnon (Amdro, SiegePro, AmdroPro, Combat, Maxforce, Probait)

- Resistance issues: None noted.
- Residual: 6-12 months.
- IPM issues: None noted.
- Other notes: Used as a bait for imported fire ants.

- REI: 12 h
- IRAC Mode of Action: 20

Neonicitinoid

Imidacloprid (Merit, Marathon, Bayer Advanced)

- Efficacy:
    - Effective against most white grub species, billbugs, mole crickets, scale insects, and other piercing-sucking insects.
    - Generally effective on mole crickets, but timing of application is critical if best results are to be achieved. The product must be applied at or just before egg hatch, and it is not effective if applied later in the season, after damage becomes apparent. Less effective than some other products on mole crickets, particularly on larger nymphs and adults.
    - Very effective as a spring preventive treatment against the billbug larval stage.
    - Can be effective on chinch bug, but timing of application is critical if best results are to be achieved. The product must be applied at or just before egg hatch, and it is not effective if applied later in the season, after damage becomes apparent. The label suggests using it for "suppression" of this insect pest.
    - In areas with historical grub infestations, preventive treatments of imidacloprid provide excellent control of young white grubs.
- Resistance issues: No resistance problems noted.
- Residual: Long residual (2-4 months). Outstanding residual activity.
- IPM issues: May be harmful to bees depending on species/time of application, however it is very safe to humans, pets and other non-target organisms.
- Other notes: Preventive insecticide applied during adult flights or egg hatching for white grub. Watering in product is essential to moving the *a.i.* into the soil where the grubs are feeding. Usable on all turf sites. Newer chemistry with reduced environmental effects. Cost of application is moderate at around $125/acre.
- REI: 12 h.
- IRAC Mode of Action Classification: 4A.

Chlothianidin (Arena)

- Efficacy:
    - May not be as effective on grubs or have as long of a residual as imidacloprid.
    - Very good control of billbug when used as a preventative or early curative.
- Resistance issues: None noted.
- IPM issues: Very low mammalian toxicity. Very low water solubility.
- Other notes: Preventive application for white grub and billbug control; newly registered; water-soluble. Less susceptible to photodegradation than imidacloprid.
- REI: 12 h.
- IRAC Mode of Action Classification: 4A.

Organochlorine

Dicofol (Kelthane)

- Efficacy:

    - Poor to sporadic control of bermudagrass and zoysiagrass mites.
- Resistance issues: Resistance to dicofol seems to be common among spider mites.
- IPM issues: Highly toxic to fish, aquatic invertebrates, and algae, but not toxic to bees. Slightly toxic to birds.
- Other notes: Two applications are typically required, and there are no other efficacious products currently labeled for bermudagrass mite, zoysiagrass mite or buffalograss mite.
- REI: 12 h.
- IRAC Mode of Action: 20.

Organophosphate

Trichlorfon (Dylox)

- Efficacy:
    - Effective curative control product for white grubs.
    - Effective on billbugs but its short residual activity makes timing even more critical. Has been used extensively in the past for billbug adult management.
- Resistance issues: Some limited resistance found.
- Residual: Very short residual, ca. 1-2 days.
- Other notes: Repeated applications often necessary. Old organophosphate that has been subject to FQPA review. It is used because it is one of the few, short-residual, curative insecticides for white grubs and billbug larvae that is still registered.
- REI: 12 h.
- IRAC Mode of Action Classification: 1B.

Chlorpyrifos (Dursban)

- Efficacy:
    - Excellent for green June beetle control, but good to fair for other grub species.
    - Used in spring for adult billbug control.
    - Good to excellent control for armyworms, cutworms and sod webworms.
- Resistance issues: No resistance problems noted.
- Residual: Excellent residual activity.
- IPM issues: May be toxic to beneficials.
- Other notes: Broad spectrum; only labeled for white grub control on sod farms and golf courses (and in nurseries); readily available and cost effective.
- REI: 12 h or 24 h depending on formulation.
- IRAC Mode of Action Classification: 1B.

Acephate (Orthene, Pinpoint)

- Efficacy:
    - Can provide good control of mole crickets if applied when nymphs are small, but is less effective on larger mole crickets. Typically, broadcast treatments soon after egg hatch (late June in N. Florida, early-mid July in North Carolina), followed by spot treatments later to control nymphs missed by the first application.
    - Good to excellent control for armyworms, cutworms and sod webworms.
    - Economical control of caterpillars.
- Resistance issues: No resistance concerns noted.

- IPM issues: Orthene is more toxic than fipronil or imidacloprid, and more water soluble, but it has been used for years with few problems.
- Other notes: Cost is considered to be relatively low, at about $50/acre. Historically used to suppress spittlebugs. Acephate has undergone label changes in recent years and can't be used in home lawns. Broad spectrum.
- REI: 24 h.
- IRAC Mode of Action: 1B.

Trichlorofon (Mocap)

- Efficacy:
    - Good to excellent control for armyworms, cutworms and sod webworms.
- Resistance issues: No resistance concerns noted.
- IPM issues: None noted.
- REI: 24 h.
- IRAC Mode of Action: 1B.

Oxadiazine

Indoxacarb (Advion)

- Efficacy:
    - Quickly reduces imported fire ant mound activity.
    - Causes rapid cessation of feeding and death of caterpillars within 48 hours.
- Resistance issues: None noted.
- IPM issues: Very low animal and environmental toxicity. Can be highly toxic to bees when it is wet on foliage, but relatively safe to beneficials when it has dried.
- Other notes: Used as a bait for imported fire ant. Considered a 'reduced risk' pesticide by EPA.
- REI: 12 h.
- IRAC Mode of Action: 22.

Phenylpyrazole

Fipronil (Chipco Choice, TopChoice)

- Efficacy:
    - The most effective insecticide available against mole crickets.
- Resistance issues: None noted.
- IPM issues: The material is generally considered of low tozicity to humans, pets and non-target organisms.
- Other notes: Use rate is 0.0125lb AI/Acre, it is very expensive ($250/acre), used as a bait formulation for imported fire ants.
- REI: 24 h.
- IRAC Mode of Action: 2B.

Pyrethroid

Bifenthrin (Talstar, Onyx)

- Efficacy:
    - Effective on large green June beetle grubs.

    - Less effective on mole crickets, particularly on larger nymphs and adults.
    - Effective on billbug adults.
    - Good to excellent control for armyworms, cutworms and sod webworms.
- Resistance issues: Southern chinch bug has shown some resistance and cross resistance to other pyrethroids may be possible.
- IPM issues: Fairly broad spectrum but low mammalian toxicity.
- Other notes: Used as a curative for billbugs. Cost is comparable to acephate. Used as a contact insecticide for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action Classification: 3.

Cyfluthrin (Tempo)

- Efficacy:
    - Effective against chinch bug if applied in high rates of water.
    - Good to excellent control for armyworms, cutworms and sod webworms.
- Resistance issues: Some indication of chinch bug resistance. No resistance concerns noted for armyworms, cutworms and sod webworms.
- IPM issues: Fairly broad spectrum but low mammalian toxicity.
- Other notes: Cost is comparable to acephate.
- REI: 12 h.
- IRAC Mode of Action: 3.

Cypermethrin

- Efficacy:
    - Effective on billbug adults.
    - Good to excellent control for armyworms, cutworms and sod webworms.
- Resistance issues: Possibility of southern chinch bug resistance.
- IPM issues: Fairly broad spectrum but low mammalian toxicity.
- REI: 12 h.
- IRAC Mode of Action: 3.

Deltamethrin (DeltaGard)

- Efficacy:
    - Good to excellent control for armyworms, cutworms, and sod webworms.
- Resistance issues: Possibility of southern chinch bug resistance.
- IPM issues: Fairly broad spectrum but low mammalian toxicity.
- Other notes: Used as a contact insecticide for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action: 3.

Lambda cyhalothrin (Demand, Scimitar)

- Efficacy:
    - Less effective on mole crickets than some other products, particularly on larger nymphs and adults.
    - Effective on chinch bug if applied in high rates of water.

    - Good to excellent control for armyworms, cutworms and sod webworms.
    - Used as a curative for billbug.
- Resistance issues: Evidence of chinch bug resistance developing. No resistance concerns noted for armyworms, cutworms and sod webworms.
- IPM issues: Fairly broad spectrum but low mammalian toxicity.
- Other notes: Cost is comparable to acephate. Used as a contact insecticide on red imported fire ant.
- REI: 24 h.
- IRAC Mode of Action: 3.

Permethrin (Astro, Permethrin Pro, Prelude)

- Efficacy:
    - Good to excellent control for armyworms, cutworms, and sod webworms.
- Resistance issues: Possibility of southern chinch bug resistance.
- IPM issues: None noted.
- REI: 12 h.
- IRAC Mode of Action: 3.

Spinosyn

Spinosad (Conserve, Naturalyte, Justice)

- Resistance issues: None noted.
- Residual: 6-12 months.
- IPM issues: None noted.
- Other notes: Used as a bait for imported fire ants.
- REI: 12 h.
- IRAC Mode of Action: 5.

Nematicides

Fenamifos (Nemacur)

- Efficacy: Efficacy is declining in many locations, possibly due to enhanced microbial degradation following regular use.
- Resistance issues: None noted.
- IPM issues: Set to be removed from market in 2008 due to environmental toxicity.
- REI: 48 h.
- IRAC Mode of Action: 1B.

1,3-dichloropropene (Curfew)

- Efficacy: Good to excellent control of ectoparasitic nematodes. Not as effective as Nemacur for control of endoparasites.
- Resistance issues: None noted.
- Residual: Very short soil residual.
- Other notes: B2 carcinogen. Fast-acting soil fumigant. Must be injected directly into soil using a knife or disk injection system. Rapid and severe phytotoxicity occurs if active ingredient contacts turf foliage.
- REI: 24 h.

Key Pest-by-Pest Profiles and Critical Issues:
Diseases

Susceptible plants, a favorable environment, and a pathogen are required for disease symptoms to develop. A disease will not develop unless these factors are present at the same time for a certain period of time. Most fungi need free water on the leaves and optimum temperatures to cause disease symptoms. Many pathogens are always present in a turf and can cause disease under favorable conditions.

Management practices that produce the best turfs do so by creating environments that are more favorable for turfgrass plants than for pathogens. Proper management is therefore one of the most important disease control methods. Turfgrass susceptibility to disease can be reduced by maintaining soil fertility at appropriate levels. Nitrogen management especially impacts disease incidence. Decreasing shade increasing air circulation and decreasing length of leaf wetness by modifying irrigation practices contribute to reducing disease potential. Modifying mowing heights and reducing compaction and thatch management also contribute.

The selection of resistant plants can also be used to limit disease problems. Some cultivars are more susceptible to diseases than others. Although advances in identifying potential biological controls for plant pathogens are increasing, few viable alternatives are available. Chemical control of diseases is often needed along with proper management practices on intensively managed turf, such as golf greens. The system of using all available disease control methods usually results in the best turf.

Fungicides can be used in preventive or curative disease control programs. One preventive disease control program is chemical application before a disease is evident but when weather conditions are favorable for disease development. This method is best for some rapidly spreading diseases such as Pythium blight. Some of the newer chemicals that control diseases for longer periods work well as preventatives. A curative control program involves chemical applications after some disease is present. This method requires rapid identification of the disease, selection of proper chemicals, and usually higher chemical rates for control.

Fungicides can be grouped into two categories: contact and systemic. Contact fungicides are sprayed on plant parts to prevent fungal infection. They protect those plant parts that are sprayed; therefore, frequent and uniform applications are necessary to insure continual plant protection. Some may control fungi on the soil or in thatch when used as a drench or when washed off the leaves. Systemic fungicides are absorbed by the plant. These fungicides may act as contacts soon after application and then they are translocated in the plant. Most are translocated upward into new growth, and some are translocated downward into the roots, also. Frequency of application is often less for systemics than for contact fungicides because the systemic chemical cannot be removed by irrigation or precipitation. Systemic fungicides are usually more specific for certain fungi; therefore, diseases must be identified accurately to select fungicides to give the best control.

Resistant strains of various fungi to fungicides may develop following repeated applications over long periods. Possible courses of action that can be taken to prevent resistance from developing include: 1) alternate use of different fungicides; and 2) use of fungicides as infrequently as possible. Continual use of low concentrations of fungicides should also be avoided as another means of reducing the potential for developing resistance.

Pest Name(s) (common, scientific): Red thread [*Laetisaria* fuciformis (McAlpine) Burds.].

Distribution, damage and importance: Circular or irregular-shaped patches of grass die rapidly during cool-moist weather. The patches may have a bleached (resembling dollar spot) or reddish color due to the presence of fungal mycelium on the foliage. These patches may merge and become larger as disease activity increases. The disease usually develops from the tip down and is characterized by the reddish mycelium (referred to as "red threads") that radiate from the tips of dead leaves under high humidity.

Host(s): Bentgrass, bluegrass, fescue and ryegrass.

Chronology: Occurs most often during the spring but can occur throughout the summer at high elevations. Red thread develops during prolonged periods of cool weather when leaves are wet from dew, fog, or frequent, light irrigations.

Control measures used and recommended:

Cultural/mechanical:

- Fertilize to meet the nutritional needs of the turf. Apply recommended amounts of nitrogen, phosphorus, potassium, and lime based on soil analysis. However, avoid overstimulation and the development of lush, succulent turf.
- Water deeply but infrequently to prevent prolonged leaf wetness. Avoid watering the turf or lawn in the late afternoon and evening.
- Prune trees and remove unwanted undergrowth to aid air movement and reduce humidity. Collect and dispose of clippings taken from infected areas to reduce the spread of the disease.
- Wash off equipment before entering noninfected areas.
- Golf course superintendents should encourage golfers to clean off their shoes between rounds.

Biological:

- None noted.

Chemical:

- Some fungicides will give good control of red thread and should be applied at the earliest stages of the disease to prevent further development.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimidazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
DMI:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
Dicarboximide:	Iprodione, Vinclozolin

EDBC (multi-site):	Mancozeb
Oxathiin:	Flutolanil
QoI (strobilurins):	Azoxystrobin, Trifloxystrobin

Pest Name(s) (common, scientific): Southern blight (*Sclerotium rolfsii* Sacc.).

Distribution, damage and importance: Southern blight first appears during hot weather as circular to crescent-shaped yellow areas. The turf dies in a ring leaving an area of green grass in the center (frog eye). These symptoms are similar to take-all patch. The rings may continue to enlarge in hot-humid weather up to 3 feet in diameter. White mycelium and small tan to brown sclerotia of the fungus are usually present at the outer edge of the rings when the disease is spreading. An unusual characteristic of this disease is that weeds, such as clover, are also killed in the spots.

Host(s): Bentgrass, bluegrass, and ryegrass.

Chronology: The fungus survives as sclerotia during the fall, winter, and spring on dead grass plants and thatch. Sclerotia germinate during hot humid weather and the fungus begins growing on organic matter and then spreads to live plants. Dry conditions followed by a rainy or humid period enhance disease development. The fungus is killed by very cold weather thus limiting the disease to warm regions.

Control measures used and recommended:

Cultural/mechanical:

- Cultural practices, such as power raking, coring, and topdressing that reduce thatch accumulation, should help control this disease.
- Fertilize to meet the nutritional needs of the turf. Submit a soil sample for analysis and apply the necessary nutrients based on the recommendations received.

Biological:

- None noted.

Chemical:

- Several contact and systemic fungicides have given good control even after symptoms have been observed.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

DMI:	Triadimefon
Oxathiin:	Flutolanil

Pest Name(s) (common, scientific): S**pring dead spot** (*Ophiosphaerella* spp.).

Distribution, damage and importance: Dead spots or patches appear in many of the same places and expand in size year after year. The symptoms on overseeded bermudagrass greens may resemble brown patch in the spring due to the dead bermudagrass showing through the overseeded grasses. Bermudagrass usually grows over the spots slowly during the summer. The areas often remain lower than the surrounding grass throughout the year and weeds frequently invade the spots. Some preemergence herbicides will slow the growth of stolons over the spots. Spring dead spot is most evident on intensively maintained bermudagrass. Lush, succulent growth late in the season and excessive thatch accumulation favor disease development. Cold weather is also a factor since the disease occurs in the northern range of adaptation of bermudagrass and is usually more severe following extremely cold winters. The disease has been observed to be more severe during springs following cool-wet falls.

Host(s): Bermudagrass.

Chronology: Dead spots or patches first appear in 3- to 5-year-old bermudagrass in the spring as bermudagrass resumes growth from winter dormancy. After the second or third year, the disease often appears as rings of dead grass as the centers of patches become recolonized with bermudagrass or weeds.

Control measures used and recommended:

Cultural/mechanical:

- Fertilize to meet the nutritional needs of the turf but do not apply excessive rates of nitrogen to overstimulate growth.
- Avoid applying nitrogen to bermudagrass beyond late August and do not exceed more than one pound of nitrogen per 1,000 square feet per application.
- Applications of potassium (about 2 pounds per 1,000 square feet) and raising the mowing height to 1 or 1½ inches in late summer should help reduce the severity of the disease.
- Reduce thatch buildup by removing cores and power raking.
- Golf greens should also be topdressed along with coring to prevent thatch accumulation.

Biological:

- None noted.

Chemical:

- Several fungicides have given good control of spring dead spot when applied at high rates in the fall (15 August to 15 October) to areas that had the disease the previous spring. Areas with the disease in the spring should be mapped for treatment in the fall because fungicide treatment is expensive.
- Spring dead spot control is a multi-year venture and is difficult to control with fungicides alone.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Education on the need for chemical and cultural, multi-year control approach.
- Education on the timing of fungicide applications.

Chemicals used:

DMI:	Fenarimol, Myclobutanil, Propiconazole
QoI (strobilurins):	Azoxystrobin

Pest Name(s) (common, scientific): Slime mold (*Mucilago, Physarum* and *Fuligo* spp.).

Distribution, damage and importance: Many small purple, white, gray, yellow, or orange fruiting bodies of these fungi may suddenly appear on leaves of turfgrasses in small patches. These fungi grow on the surface of leaves and do not kill the leaves, but may cause some yellowing by shading the affected leaves. Slime molds are unsightly but are not considered harmful. Spores survive in the soil and on thatch. May occur throughout the Southern Regions, but generally are not considered a major pest.

Host(s): All turfgrasses.

Chronology: Slime molds usually appear during or after extended periods of warm wet weather. The spores germinate and develop into a colorless, slimy mass that grows over the soil and nearby plant parts during wet weather.

Control measures used and recommended:

Cultural/mechanical:

- The slime molds may be removed by brushing, mowing, or washing the turf.

Biological:

- None noted.

Chemical:

- Fungicides are not needed, but some can be used to control these fungi if the problem is too unsightly.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- None noted.

Chemicals used:

- Chemicals are not required to control this pest.

Pest Name(s) (common, scientific): Brown patch (*Rhizoctonia* spp.).

Distribution, damage and importance:

- One of the most common and important diseases of all warm and cool season grasses in the Southern Regions.

- Symptoms of brown patch are brown or tan patches of diseased turf ranging in diameter from 5 cm (2 in.) up to 1 m (3 ft) or more in diameter. When close-cut turf (<2.5 cm or 1 in.) is wet, brown patches are often surrounded by a dark brown or gray ring called a "smoke ring". The smoke ring is evidence of active fungal growth on the turf foliage and is an initial sign of brown patch development.
- Brown patch typically does not result in damage to all tillers within a developing patch; therefore, the turf may recover when disease pressure is reduced by change in weather conditions or implementation of control practices. Visually, healthy grass will be seen within diseased patches.
- Symptoms observed on individual plants vary according to the height of mowing. On turf maintained above 2.5 cm (1 in.), irregular silver-gray or tan lesions with a thin, dark brown border are observed on the leaves. On close-cut turf (<2.5 cm or 1 in.), no distinct lesions are readily observed, but the symptoms appear as general leaf necrosis.
- Poor soil drainage, prolonged leaf wetness, excessive thatch, high levels of nitrogen application, mowing when wet and leaf fraying by dull blades have all been associated with enhanced disease severity.

Host(s): Bentgrass, bluegrass, ryegrass and tall fescue. Occurs less commonly on warm season turfgrasses.

Chronology: Commonly occurs during periods of warm and humid weather (above 85°F) and when night temperatures continually exceed 60°F and foliage remains moist for prolonged periods. Another type of cool-weather brown patch that is often called yellow patch occurs on bentgrass. This disease develops during extended periods of cold-wet weather in the winter.

- Warm season turfgrasses: disease of the spring and fall, except in Florida and south Texas where it is also found in the winter.
- Cool Season grasses: In Florida and south Texas winter – spring, in other coastal southern states, a disease of summer.
- In the northern tier of the southern region, such as OK, AR, TN, VA it is a disease of summer.

Control measures used and recommended:

Cultural/mechanical:

- Moisture and temperature are the most common factors limiting brown patch development. Practices that reduce the amount of time that the turf canopy is wet or humid will therefore reduce the severity of brown patch.
- Irrigation water should be applied infrequently, but in sufficient amounts to meet the water requirements of the turf. Irrigation should be timed so that the duration of leaf wetness is minimized. Early morning mowing also reduces leaf wetness duration by removal of large dew droplets and gutation water from the leaves.
- In areas where sunlight penetration and air movement are low, pruning or removal of surrounding trees and shrubs will help to reduce brown patch development by facilitating water evaporation and improving overall turf vigor.
- Poor soil drainage also enhances brown patch. Where soil drainage is poor, installation of drainage tile, core cultivation to reduce soil compaction and thatch accumulation, and/or

modification of the soil profile to increase porosity will reduce brown patch severity and improve overall turf quality.
- Excessive levels of nitrogen fertilizer enhance brown patch activity. Nitrogen fertilizer should be applied in small quantities during the summer months to reduce brown patch severity. Avoid excess, fast release nitrogen.
- Remove grass clippings.
- Use of resistant cultivars.

Biological:
- None noted.

Chemical:
- Applications of effective fungicides when the first symptoms appear will give good control of brown patch on cool-season grasses.
- Fungicides in the following classes are effective for brown patch control: carboximides, benzimidazoles, carbamates, dicarboximides, DMI inhibitors, nitriles, and Qo inhibitors. DMI class fungicides and Myclobutanil can be used without much risk from phytotoxicity.
- In warm, humid climates, where brown patch pressure is consistent throughout the summer months, preventative, calendar-based applications are recommended for brown patch control. In more temperate climates, where disease development occurs intermittently, applications may be made on a curative basis or according to a disease forecasting system.
- Fungicides are very important in golf courses, sports fields and commercial and residential turf.
- No resistance known.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: Development of resistant cultivars.

Chemicals used:

Benzimidazole:	Thiophanate-methyl
Carbamate (DMDC):	Thiram
DMI:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
EDBC (multi-site):	Mancozeb
Oxathiin:	Flutolanil
Substituted aromatic:	PCNB

Pest Name(s) (common, scientific): Large patch (Rhizoctonia blight, *Rhizoctonia solani* Kühn).

Distribution, damage and importance: The disease appears as roughly circular patches, from one foot to several yards in diameter that are orange, yellow, reddish-brown, or tan in color. The outer edges of the patches are often bright orange or red in color when the disease is actively

developing. Individual plants tend to pull up from the turf easily, and close examination of leaf sheaths reveals the presence of lesions and significant rotting.

Hosts: Centipedegrass is by far most susceptible to large patch, followed by St. Augustinegrass and zoysiagrass. The disease occurs occasionally on bermudagrass, but this grass recovers from the damage very rapidly. Bentgrass, bluegrass, ryegrass, St. Augustinegrass, tall fescue**,** bermudagrass, centipedegrass and zoysiagrass.

Chronology:

- Large patch begins to develop in the fall when soil temperatures decline to 70°F. The disease continues to develop throughout the fall and spring as long as cool, wet weather persists.
- Symptoms usually become evident in spring as the turf greens up, but in severe cases, symptoms may become evident in the fall.
- Large patch develops on warm-season grasses in the fall and spring, as these grasses are going into or coming out of winter dormancy.

Control measures used and recommended:

Cultural/mechanical:

- High nitrogen levels in the fall and spring, excessive thatch, low mowing heights, poor soil drainage, and excessive irrigation are factors that encourage large patch development.
- Proper site design, construction, and turf selection are very important for large patch management. Avoid growing turf in areas surrounded by trees or in low-lying areas where water will collect. Centipedegrass is highly susceptible to large patch and should not be planted in areas prone to the disease. Avoid application of nitrogen to warm-season turfgrasses in the fall and spring when these grasses are growing slowly. Mow at the height recommended for each turf species, and cultivate as needed to control thatch and alleviate soil compaction.
- Turfgrass species vary significantly in their susceptibility to *Rhizoctonia* species. Among the bentgrass species used for golf course turf, creeping bentgrass is more resistant to *R. solani* than colonial bentgrass. For lawn and landscape turf use, Kentucky bluegrass and fine fescue species are often observed to be more resistant to *R. solani* than tall fescue or perennial ryegrass.

Biological:

- None noted.

Chemical:

- Fungicides are effective for large patch control, but must be applied preventatively in the fall for maximum effectiveness. In areas where large patch has been a problem, begin fungicide applications in the fall when soil temperatures decline to 70°F for several consecutive days. Repeat applications on 4 to 6 week intervals until the turf goes dormant may be necessary in severe cases. Spring applications are not necessary or highly effective.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- More work needed on biological based materials.
- More work needed on developing plant resistance and sustainable landscapes.

Chemicals used:

Benzimadazoles:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation Inhibitors (DMIs):	Myclobutanil, Triadimefon, propiconazole
Dicarboximides:	Iprodione
Polyoxins:	Polyoxin D zinc salt
Oo Inhibitors (strobilurins):	Trifloxystrobin, Azoxystrobin, Pyraclostrobin, Fludioxonil

Pest Name(s) (common, scientific): Dollar spot (*Sclerotinia homoeocarpa* FT Bennett).
Distribution, damage and importance: Regionally important on all turf grass species. Most important in golf course overseeded with Bermuda grasses and Seashore paspalum and year round on Bentgrasses. Small, circular areas of turf about 2 inches in diameter are affected. Spots may merge to form large, irregular areas. First signs of disease appear as patches of bleached grass on higher cut turf and small circular spots on very low cut turf. Individual leaf blades display tan lesions with reddish margins. Fine white, cobwebby fungus threads may be seen in early morning on the infected grass. Moderate temperatures (60-80F), excess moisture, and excess mat and thatch favor dollar spot. Incidence is higher in drought stressed areas. Nitrogen- and potassium-deficient turf develops more dollar spot than adequately fertilized turf.

Hosts: All turf species. Most common on: creeping bentgrasses, annual bluegrasses, perennial ryegrasses, fine-leaf fescues, colonial bentgrass, Kentucky bluegrass, bermudagrass and zoysiagrass.

Chronology:

- Seasonably variable depending on turf type.
- The disease develops most rapidly during warm-moist weather in the spring and fall when heavy dews occur. It can continue to develop during humid weather throughout the summer. The disease often develops earlier in the spring where it was not adequately controlled the previous fall.

Control measures used and recommended:

Cultural/mechanical:

- Apply adequate nitrogen and potassium.
- Utilize frequent mowing and clipping collection in order to outgrow the pathogen.
- Remove dew by irrigating lightly in the morning to reduce prolonged leaf wetness, as opposed to dragging a hose over the area or using a whipping pole on golf greens, which may spread the disease.
- Remove excess thatch by power raking to reduce the potential for reinfection. Golf greens should be regularly cored and topdressed to reduce thatch buildup.

- Water only when needed and to depth of 4-6in.
- Use of resistant cultivars is one of the best means of prevention.
- Plant blends and mixtures of cool-season grasses whenever possible.
- Allow for better air movement and reduced humidity by clearing barriers such as unwanted vegetation and relocating desirable plants.
- Avoid spreading the disease by washing equipment before entering a noninfected area, by encouraging golfers to clean their shoes between rounds, and removing and disposing of clippings taken from infected areas.

Biological:

- None so far. Work with biological fungicides has just commenced and needs much more research.

Chemical:

- Fungicides are very important in the management of this disease, however resistance is common.
- Fungicides most effective if applied as a preventative in the early spring and fall
- Fungicides are available that will control dollar spot; however, some strains of dollar spot have developed resistance to some fungicides. Other fungicides are effective in controlling these strains of the fungus. Alternate use of different fungicides labeled for the control of dollar spot and good management practices are the most practical approaches to control.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:
Research is greatly needed on:

- Isolate variability and epidemiology.
- Management methods to reduce reliance on fungicides and fungicide resistance.
- Cultivar (plant) resistance.

Chemicals used:

Benzimadazoles:	Thiophanate-methyl
Carboxamides:	Boscalid
Demethylation Inhibitors:	Myclobutanil, Propiconazole, Triadimefon
Dicarboximides:	Iprodione, vinclozolin
Pyrimidines:	Fenarimol
Substituted aromatics:	Chlorothalonil

Pest Name(s) (common, scientific): Fairy ring (Many basidiomycete-type fungi, which often produce mushrooms and puffballs in association with fairy rings).

Distribution, damage and importance:

- A dark green band of turf develops in a circle or semicircle; mushrooms may or may not be present. Frequently, just behind the dark green bands is an area of sparse, brown, dying grass, caused by lack of water penetration. Mats of white fungal mycelium may be

seen in the soil. Weed invasion is common. Effects may be less on grass species with long stolons. Develops most frequently in soil that is high in organic matter, such as undecomposed thatch. Drought stressed, nutrient deficient turf may be more susceptible.

Hosts: All turfgrasses.

Chronology: The symptoms of any fairy ring may change throughout the year. Mushrooms or puffballs are present more often in the late summer and fall during wet weather. These fruiting bodies may never appear or may appear only in certain years.

Control measures used and recommended:

Cultural/mechanical:

- More drastic methods of control in cases of severe infestations or highly managed areas it may be necessary to remove infested sod and soil and replace with clean soil and reseed or sod. Soil fumigation or turf renovation by rototilling and mixing the soil and replanting are also options.
- Apply adequate nitrogen.
- Remove thatch periodically.
- Aerate soil to improve water penetration and apply water heavily in holes every day for 3-10 days. Wetting agents may also be used to increase water penetration. Infected areas should be hand watered to prevent overwatering of the entire area, which may prove harmful to the uninfected turf.
- Removal of large sources of organic material such as stumps (and waste lumber in new construction sites) before an area is planted can help prevent disease development.by these fungi.
- Fertilize to meet the nutritional needs of the turf or lawn.
- Do not attempt to mask the fairy ring symptoms on cool-season grasses during the summer with nitrogen because this may result in overstimulation of the grass and the development of more serious diseases.

Biological:

- None noted.

Chemical:

- Some fungicides drenched into the soil may control fairy rings.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Carboxamide:	Flutolanil
Demethylation inhibitor:	Myclobutanil
Strobilurins (Methoxyacrylate):	Azoxystrobin

Pest Name(s) (common, scientific): Microdochium patch, pink snow mold [*Microdochium nivale* (Fries) Samuels & Hallett].

Distribution, damage and importance: Circular patches develop during cold-wet weather beginning as small areas that continue to enlarge during favorable weather conditions. The disease may cause patches up to 6 inches in diameter without snow cover and up to 2 feet in diameter under snow. The grass first appears water soaked but then turns light tan in color. Patches may be first covered with white mycelium that becomes pink from mycelium and masses of spores. Restricted air movement, poor soil drainage, lush, succulent growth, inadequate levels of potassium and traffic on frosted turf can enhance disease as well as excessive leaf growth and thatch buildup going into the winter. The disease often develops under tree leaves that remain on the turf for long periods during cold-wet weather.

Hosts: Annual bluegrass, creeping bentgrass, fine-leaf fescues, perennial ryegrasses, Kentucky bluegrass.

Chronology: Disease activity is most severe when snow falls on unfrozen ground; however, activity can occur in the absence of snow cover anytime maximum temperatures are below 60°F.

Control measures used and recommended:

Cultural/mechanical:

- Avoid overstimulation of the turf going into the winter by not applying heavy rates of nitrogen just before cold-wet weather is predicted or before the first expected prolonged snow cover. Apply a high potassium analysis fertilizer in late fall to increase cold hardiness of the turf.
- Erect snow fences or plant landscape plants in strategic locations to prevent excess snow accumulation on highly maintained turf (for example, a golf green) or where snow mold has been a serious problem.
- Prune trees and remove unwanted vegetation that impedes air movement.
- Continue mowing in the fall until growth stops. This will prevent a buildup of excess foliage that may allow for prolonged leaf wetness.
- Frequently remove fallen tree leaves during autumn and winter from turf that is not covered with snow.
- Rake or spike infected areas in the spring to hasten drying and create a more favorable environment for recovery.
- Direct traffic away from potentially diseased areas and power rake or core previously infected areas to reduce thatch buildup.
- Improve surface drainage of previously infected areas to reduce extended periods of wetness.

Biological:

- None noted.

Chemical:

- Fungicides must be applied before snow cover to prevent disease development under snow. In areas that snow cover is not a problem certain fungicides can be applied when the disease is first observed.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimadazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation inhibitor:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
Dicarboximide:	Iprodione, Vinclozolin
EDBC (multi-site):	Mancozeb, Thiram
Phenylpyrrole:	Fludoxonil
Polyoxin:	Polyoxin D zinc salt
Substituted aromatic:	PCNB quintozene
QoI (strobilurins):	Azoxystrobin, Trifloxystrobin, Pyraclostrobin

Pest Name(s) (common, scientific): Powdery mildew [*Blumeria graminis* (DC.) E.O. Speer].

Distribution, damage and importance: A white to gray powdery growth of fungus mycelium develops on infected leaves. Heavily infected leaves turn yellow and die slowly resulting in weakened plants that may be killed by environmental stresses. Unlike many other fungi, free water on leaves is not required for infection by *Blumeria* spp. The disease is usually more severe in shaded areas with poor air circulation during long periods of dry weather.

Host(s): Bluegrass.

Chronology: The fungus survives the winter in living plant tissue. Spores are produced in the spring and are spread to healthy tissue by wind. The spores germinate and infect leaves during cool-humid conditions in the spring and fall.

Control measures used and recommended:

Cultural/mechanical:

- Planting shade-tolerant grasses is one of the best means of preventing the incidence of powdery mildew. Most shade-tolerant grasses have exhibited some degree of tolerance to this disease.
- A combination of two or three bluegrass cultivars or bluegrass in combination with tall or fine fescue is preferred.
- Proper fertilization to avoid lush growth, higher mowing heights, and irrigation to prevent drought stress and prolonged moisture will help infected plants overcome the disease.
- Apply no more than one pound of nitrogen per 1,000 square feet at any one time to bluegrass.
- Maintain mowing height above 2 inches to enhance rooting and provide greater leaf surface for food production.

- Water deeply but infrequently to a depth of 6 to 8 inches to enhance rooting and reduce the period of leaf wetness. Avoid light, frequent watering and watering in late afternoon and evening.
- Pruning, removal, or careful placement of trees and shrubs to improve light intensity and air movement will help control powdery mildew.

Biological:
- None noted.

Chemical:
- Several fungicides can be used to control this disease.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimidazole:	Thiophanate-methyl
Demethylation inhibitor:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
QoI (strobilurins):	Azoxystrobin, Trifloxystrobin

Pest Name(s) (common, scientific): Smuts (*Ustilago* spp.).
Stripe smut [*Ustilago striiformis* (Westendorp) Niessl] and **loose smut** [*Ustilago cynodontis* (Passerini) Hennings].

Distribution, damage and importance:
- *Stripe smut:* plants are often pale green and stunted. Long, black stripes of spores are apparent. Infected leaves curl and die and become shredded in appearance.
- *Loose Smut:* flower heads are replaced by masses of dark spores. Fungus remains in infected plants the year round. Show symptoms principally at flowering. Most prevalent in warm weather and under conditions that promote flowering.

Hosts: *Loose smut*: common bermudagrass; *Stripe smut*: Kentucky bluegrass, creeping bentgrass.

Chronology:
- For both smuts, the fungus remains in infected plants year round and may contaminate seed and infect seedlings and young tillers.
- Symptoms most often are seen in times of moderate temperatures in the spring and fall.

Control measures used and recommended (pros and cons of each method):
Cultural/mechanical:
- *Stripe Smut*: Reduce nitrogen. Irrigate to prevent dormancy.
- *Loose Smut*: Keep grass growing vigorously and remove flower heads by mowing before spores are produced.

Biological:

- None noted.

Chemical:

- Because fungus spores may cling to seeds or occur in soil. Seed treatment with suitable fungicides such as captan will prevent infection from seedborne or soilborne spores.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimadazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation inhibitor:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
Pthalamide (multi-site):	Captan
QoI (strobilurins):	Azoxystrobin, Trifloxystrobin

Pest Name(s) (common, scientific): Rusts (*Puccinia* spp. and *Uredo* spp.).

Distribution, damage and importance: Early symptoms include small yellow flecks that develop on the leaves and stems. The infected spots on leaves develop into orange or red pustules that may rupture over time, exposing and releasing masses of yellow, orange, red, or dark brown microscopic spores. These spores can infect more tissue and plants until the infected turf takes on the color of the spores. Heavily infected areas will exhibit clouds of orange dust (rust spores) when the foliage is disturbed. Infected plants become yellow and are more susceptible to environmental stress. Thinning of the turf or lawn often occurs on heavily infected areas. Free water on the leaves for certain periods of time is necessary for the spores to germinate and for the disease to develop rapidly. The disease is more severe under conditions of low fertility. Disease is also more severe on turf subjected to drought stress, low mowing, shade or poor air circulation.

Hosts: Almost all warm season grasses. Kentucky bluegrass, perennial ryegrass, zoysiagrass, bermudagrass, tall fescue.

Chronology: The fungus survives the winter in living plant tissue from which new spores are produced in the spring. The spores that are produced in the spring, summer, and fall are spread by the wind, germinate on the leaves, and infect new tissue. Many cycles of spores can be produced during the year.

Control measures used and recommended:

Cultural/mechanical:

- Provide adequate levels of nitrogen.
- Mow frequently.
- Planting rust resistant turfgrass cultivars whenever possible will reduce potential injury from this disease.

- Use blends and mixtures of cool-season grasses whenever possible.
- Plant shade tolerant grasses and avoid close mowing where shade prevails.
- Prune trees and remove unwanted undergrowth to improve air movement and reduce prolonged leaf wetness.
- Collect and dispose of clippings taken from infected areas to avoid spread of this disease.
- Wash equipment before entering noninfected areas.
- Water deeply but infrequently to encourage deep rooting and reduce drought stress and extended periods of leaf wetness. Avoid watering the turf in late afternoon and evening.

Biological:

- None noted.

Chemical:

- Several fungicides can be used to control rust diseases when cultural practices fail.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimidazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation inhibitor:	Myclobutanil, Propiconazole, Triadimefon
EDBC (multi-site):	Mancozeb
QoI (strobilurins):	Trifloxystrobin

Pest Name(s) (common, scientific): Gray leaf spot [*Pyricularia grisea* (Cooke) Sacc.].

Distribution, damage and importance: Gray leaf spot begins as small lesions on leaves and stems during warm, humid weather. In time, the lesions enlarge to circular or oval shaped spots that are tan in the center and bordered with a purple to brown margin. A gray growth may cover the lesions during warm, humid weather. Severely affected leaves may wither and die, and St. Augustinegrass may appear brown.The disease is more severe in shady areas or during cloudy weather under conditions of high nitrogen fertility.

Host(s): Affects most warm season grasses although St. Augustinegrass is most susceptible. Perennial ryegrass and tall fescue also severely affected.

Chronology: The fungus survives as mycelium and spores on infected plant tissue. Spores are produced during warm, humid weather and are spread by wind, water, and mowing. The disease is more severe on immature plants and in turf that has been fertilized with high rates of nitrogen.

Control measures used and recommended:

Cultural/mechanical:

- Daytime irrigation.

- Select slow-release fertilizers or limit the amount of quick-release nitrogen applied to St. Augustinegrass when warm-humid weather is expected. In general, do not exceed one pound of nitrogen per 1,000 square feet per month during the months of July and August especially on newly planted St. Augustinegrass. Avoid late afternoon and evening waterings to reduce the duration of leaf wetness.
- Prune trees and remove undergrowth to aid in air movement and allow for light penetration.
- Use of resistant cultivars.

Biological:
- None noted.

Chemical:
- Fungicides are available that will effectively control gray leaf spot. Repeat treatments may be necessary if conditions favoring the disease persist.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: Development of resistant cultivars.

Chemicals used:

Benzimadazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation inhibitor:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
EDBC (multi-site):	Mancozeb (used in combination with copper hydroxide)
OoI (strobilurins):	Azoxystrobin, Pyraclostrobin, Trifloxystrobin
Inorganic:	Copper hydroxide (used in combination with mancozeb)

Pest Name(s) (common, scientific): Helminthosporium diseases (*Helminthosporium* spp.[now known as *Bipolaris, Drechslera,* and *Exserohilum* spp.].

Distribution, damage and importance: Black to brown spots appear on leaf blades and leaf sheaths. Spots may be tan in the center. Lower leaves are shriveled and blighted. These pathogens can also affect root and crown areas causing thinning or "melting out" of the turf. Areas may at first appear chlorotic (yellow) and then may turn brown and die if the disease is severe. These fungi can also cause seedling blights on recently planted turfgrasses such as winter overseeding. The disease is most severe under conditions of high nitrogen application, when mowing height is less than 2 inches and temperatures are 75-90 ^{o}C and leaf wetness exceeds 10 hours per day for several days. Drought stress and continual mowing at close heights are also factors that encourage the development of Helminthosporium diseases. Shaded areas with little or no air movement result in weak turf and extended periods of leaf wetness that favor disease development and plant infection. Certain cultivars of turfgrasses are very susceptible to injury from Helminthosporium diseases while many of the newly released cultivars have exhibited good resistance.

Host(s):

- *Leaf Spot* [*Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem.]**:** Kentucky bluegrasses, perennial ryegrasses, fine-leaf fescues, creeping bentgrass.
- *Melting out* (*Helminthosporium vagans* Drechel.): Kentucky bluegrass.
- ***Melting out*** (***Helminthosporium sorokinianum*** Sacc. in Sorokin.): Bentgrass, bluegrass, fescue, ryegrass, and bermudagrass.
- ***Leaf blotch*** (*Bipolaris cynodontis* F. Sugawara): Only bermudagrass.

Chronology: Some of these diseases can develop anytime during the year. The fungi survive in thatch during unfavorable periods for disease development. Many of the leaf spot diseases become most active during periods of cool-moist weather.

Control measures used and recommended:

Cultural/mechanical:

- Some turfgrass cultivars have been developed with resistance to these diseases and should be used when available. Use of resistant cultivars is one of the best means of prevention.
- Use blends and mixtures of cool-season grasses whenever possible.
- Fertilize to meet the nutritional needs of the turf but avoid overstimulation and the development of lush, succulent growth. In general, turfgrasses should not receive more than one pound of nitrogen per 1,000 square feet in a single application.
- Avoid excess nitrogen fertilizer on cool-season grasses in late spring and summer.
- Avoid continual close mowing of the turf by raising the cutting height whenever possible.
- Keep the mower blades sharp to reduce the area of open wounds in which the disease agents can enter.
- Reduce extended periods of leaf wetness by watering deeply but infrequently to a depth of 6- to 8-inches. Avoid late afternoon and evening waterings and insure good surface and soil drainage. Remove unwanted vegetation that impedes air movement and prune trees to allow for light penetration. Relocate landscape plants to insure good air drainage.
- Power rake to remove excessive thatch and reduce the potential for reinfection. Coring and topdressing golf greens on a regular basis will also reduce thatch buildup.

Biological:

- None noted.

Chemical:

- Fungicides are available that will control these diseases. They should be applied when leaf spot is active and in the early stages of development for best control and to reduce crown infections that can kill the plants.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Chlorophenyl (multi-site):	Chlorothalonil
Dicarboximide:	Iprodione, Vinclozolin

EDBC (multi-site):	Mancozeb
Polyoxin:	Polyoxin D zinc salt

Pest Name(s) (common, scientific): Pythium blight and seedling diseases (*Pythium* spp.).

Distribution, damage and importance: Small, sunken patches, from 1- to 12-inches in diameter, appear during warm and humid weather. The patches often resemble the early stages of hot weather wilt. Gray, cottony mycelium may be seen in the infected areas during very humid weather along with greasy, water-soaked, blackened leaves that become matted. The water-soaked leaves often feel greasy and turn straw colored when the turf dries. The disease spreads rapidly along drainage patterns and can be tracked by equipment. This disease can cause severe damage quickly because of its rapid spread when conditions are favorable for development. Entire golf greens have been lost in less than 24 hours due to this disease. Root rot diseases caused by several *Pythium* species may develop during hot or cool weather. These diseases usually result in a thinning or decline of the turf. Excessive soil moisture and succulent growth favor disease development. Pythium blight and the root rot disease are likely to develop on cool-season grasses during extended periods of warm-wet weather. Young seedlings are very susceptible to these diseases.

Hosts: Affect all turfgrasses although warm season grasses are generally less susceptible than cool season grasses. Annual bluegrass, perennial ryegrass, fine-leaf fescue, bentgrass and tall fescue.

Chronology: Primarily occurs during warm, wet, humid weather. Regionally very important seasonal pest of overseeded turfs (Fall-Spring). Also of great importance in bentgrasses of the Gulf coast states (Summer). Pythium blight becomes very active when relative humidity is high and day and night temperatures exceed 85°F and 68°F, respectively.

Control measures used and recommended:

Cultural/mechanical:

- Improve soil aeration and drainage.
- Increase circulation by removing surrounding vegetation.
- Avoid frequent irrigation.
- Minimize equipment and foot traffic across turf.
- Wash/disinfect equipment that has been in infected areas. Golf course superintendents should encourage members to clean their shoes between each round.
- Avoid excessive rates of nitrogen to prevent the development of lush, succulent growth. Such growth is very susceptible to injury by Pythium blight, especially when conditions are favorable for disease development.
- Collect and promptly dispose of clippings on infected areas.
- When overseeding or establishing sod, as with mature turf, avoid overwatering and make every effort to reduce the time in which the young seedlings remain wet between waterings.

Biological:

- None noted.

Chemical:

- Fungicides are crucial for prevention.
- Only certain fungicide groups are efficacious and resistance is known in mefenoxam and azoxystrobin. Rotations with different FRAC classes are important.
- Use fungicide-treated seed (if available) when seeding new areas and especially when overseeding golf greens if Pythium blight has been a problem in the past. If untreated seed is used, spray just before or after seeding with a fungicide that will control *Pythium* species.
- Due to the potential rapid development of this disease and loss of large areas of turf; managers, especially golf course superintendents, should consider a preventive fungicide program when hot-humid weather is forecast and Pythium blight has been a problem in the past.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Further research to examine Pythium species involved. Multiple species are common and need identification to identify pathogenic species and resistance patterns to fungicides.
- Need to examine the role of currently available and potential future biological agents.
- Best management practices need definition.

Chemicals used:

Aliphatic nitrogen compounds:	Propamocarb hydrachloride
EDBC (multisite):	Chloroneb, Mancozeb (for pythium blight but not pythium root rot)
Organophosphate:	Fosetyl Al
Phenylamide:	Metalaxyl mefenoxam
Phosphonates:	Phosphorous acid
Thiazoles:	Etridiazole
QoI (strobilurins):	Azoxystrobin

Pest Name(s) (common, scientific): Curvularia fading out or **curvularia blight** (*Curvularia* spp.).

Distribution, damage and importance: cause yellow to red-brown irregular shaped patches of thin turf. Leaves may appear yellow to gray starting at the leaf tip. Roots, stolons and rhizomes may also become infected. A fine, grey layer of mycelia may cover infected tissues, and there is often an abundance of sporulation from infected and dead tissue. This is primarily a stress pathogen that attacks low fertility and heat and drought stressed plants.

Host(s): Bermudagrass and zoysiagrass are especially susceptible among the warm season grasses. Annual bluegrass, bermudagrass, bentgrass and fescue.

Chronology: Damage often occurs when temperatures are 85°F or higher.

Control measures used and recommended:

Cultural/mechanical:

- Reduce thatch.
- Maintain high mowing height.
- Fertilize based on soil tests.
- Reduce prolonged leaf wetness.
- Water infrequently but deeply to avoid drought stress.

Biological:

- None noted.

Chemical:

- Fungicides may be warranted on golf greens during long periods of high temperatures.
- Both chlorothalanil and iprodione have been shown to be effective.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Chlorophenyl (multi-site):	Chlorothalonil
Dicarboximide:	Iprodione

Pest Name(s) (common, scientific): Anthracnose (*Colletotrichum graminicola* (Ces.) Wils.).

Distribution, damage and importance: Irregular patches of diseased turf 2 to12 inches in diameter. Leaf blotches are brown, fading to light tan. Fungus forms minute black fruiting structures (acervuli) on dead grass blades. Low nitrogen, soil compaction and excessive thatch contribute to disease severity.

Hosts: All turfgrasses, but more common on cool season turfs. Particularly susceptible: Annual bluegrasses, creeping bentgrasses, tall fescues, fine-leaf fescues. Warm turfs that are susceptible: bermudagrass, centipedegrass and St. Augustinegrass.

Control measures used and recommended:

Cultural/mechanical:

- Maintain vigorous turf with proper fertilization and irrigation.
- Aerate turf and remove excess thatch.

Biological:

- None noted

Chemical:

- Several fungicides may be helpful when the disease is particularly severe.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Benzimadazole:	Thiophanate-methyl
Chlorophenyl (multi-site):	Chlorothalonil
Demethylation inhibitor:	Fenarimol, Myclobutanil, Propiconazole, Triadimefon
Polyoxins:	Polyoxin D zinc salt
QoI (strobilurins):	Trifloxystrobin, Azoxystrobin, Pyraclostrobin

Pest Name(s) (common, scientific): Patch diseases
Pink patch (*Limonomyces roseipellis* Stalpers & Loerakker), **spring dead spot, summer patch** (*Magnaporthe poae* Landschoot & Jackson) and **take-all patch** [*Gaeumannomyces graminis* var. *avenae* (Turner) Denni].

Distribution, damage and importance:

- *Spring dead spot*: Circular patches of straw colored turf appear in bermudagrass up to several feet in diameter as turf emerges from winter dormancy. Roots at edges of patch are dark brown to black. Several species of fungi have been implicated. Late summer, fall applications of nitrogen and soils low in potash and poor drainage may contribute to disease incidence.
- *Summer patch*: Appears as circular yellow or tan areas up to 1 foot in diameter, consisting of dead and dying plants. Roots, crowns, and stolons are affected by a dark brown rot. Young roots may appear healthy, although dark brown hyphae may be present on these tissues. Vascular discoloration and cortical rot occur in later stages of the disease. On occasion, patches may retain centers of green, apparently unaffected grass. The fungus can survive as mycelia in plant debris or in host tissue. Infections occur when soil temperatures are consistently at 65° to 70°F, and symptoms tend to appear when air temperatures are 83° to 95°F or higher. The disease is most severe on closely mowed turf (e.g. golf greens) with heavy irrigation or high soil moisture.
- *Take-all patch*: appears in late spring as circular yellow patches that turn brown in early summer. The disease often occurs in the mountains of North Carolina during the first and second years after bentgrass is seeded on greens or on fairways that were cleared in forest land. Other grasses such as annual bluegrass or fescue usually grow in the center of the dead spots. The patches may continue to develop for several years and increase in size up to 3 or more feet in diameter. The severity of take-all patch usually decreases after several years as beneficial microorganisms build in the soil. The roots, stolons, and crowns of diseased plants are dark brown to black. Dark strands of mycelium can usually be seen with low magnification on the diseased tissues. Take-all develops most often in sterilized soils on golf greens, especially on greens with high sand content. Disease development is favored by cool-wet conditions in the fall and spring. High soil pH and low manganese availability enhances the development of take-all.

Host(s):

- *Pink Patch*: Fine-leaf fescue, tall fescue, perennial ryegrass, colonial bentgrass, creeping bentgrass, annual bluegrass.

- *Spring Dead Spot*: Bermudagrass.
- *Summer Patch*: Kentucky bluegrass, annual bluegrass.
- *Take-all patch*: Creeping bentgrass, colonial bentgrass.

Control measures used and recommended:

Cultural/mechanical:

- *Pink Patch:* Provide adequate levels of nitrogen.
- *Spring Dead Spot:* Avoid late-season application of nitrogen.
- *Summer Patch:* Apply light, frequent watering during dry periods to reduce heat stress. Do not water heavily or deeply. Provide adequate nitrogen.
- *Take-All Patch:* Avoid drought stress. Patches of bentgrass killed by take-all recover slowly. Aerification and reseeding dead patches should aid in recovery. Resodding or plugging patches on golf greens may be practical. Maintenance of soil pH near 5.5 also helps restrict take-all patch development. Avoid high soil pH by not applying too much lime and use acid forming nitrogen fertilizers. Correcting problems with irrigation water quality can also help to prevent high soil pH.

Biological:

- None noted.

Chemical:

- Avoid application of elemental sulfur, which is directly toxic to bentgrass and may cause the formation of black layer.
- In combination with reduced soil pH, applications of manganese on 4 to 6 week intervals in the fall and spring (total of 2 pounds of Mn per acre per year) provide significant control of take-all patch.
- Several systemic fungicides have been labeled for the control of take-all patch. These fungicides should be applied preventatively in the fall for best results.
- When cultural recommendations fail to control these patch diseases, fungicides are recommended for control, particularly if the diseases have been a problem in the previous year.
- In areas where summer patch is frequent, begin fungicide applications when soil temperatures begin to be consistently in the 65° to 70°F range. This may be 3 to 4 weeks before symptoms are typically seen.
- Fungicide applications made after strong symptom expression are generally ineffective.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

- *Pink patch*: Fenarimol, Myclobutanil, Triadimefon, Propiconazole (DMI).
- *Spring dead spot*: Fenarimol, propiconazole, benomyl, thiophanate methyl, myclobutanil.

- *Summer patch*: Azoxystrobin, Pyraclostrobin (OoI), Fenarimol, Myclobutanil, Propiconazole, Triadimefon (DMI), before symptoms are evident; Thiophanate-methyl (Benzimidazole), after symptoms are evident.
- *Take-all patch*: Fenarimol, myclobutanil, propiconazole (DMI).

Overall Needs for Management of Disease Pests of Turf

Regulatory:

- Regulation of soil and plant material movement related to nematodes needs improvement regarding the follwing pests in particular:
    - Reniform and citrus nematodes.
    - Soybean cyst nematode important if planning to ship into Canada.
- Regulations among states and/or countries needs to be harmonized to streamline permit process. This is particularly important in regards to research materials.

Education:

- Better ways to communicate disease management strategies.
- Fungicide resistance management.
- Disease prediction related to best management practices.

Research:

- Root health regarding fungi that are not well known (biology).
- Interactions between pathogens including nematodes.
- Need for fumigation alternatives.
- More information about soil mixes related to root health.
- Cultural options for pathogen management.
- Disease prediction related to best management practices.

Fungicides used

Aliphatic nitrogen compound

Propamocarb hydrachloride (Banol)

- Efficacy: Excellent preventative control of Pythium foliar diseases. Curative activity against Pythium foliar diseases more slow than mefanoxam. Activity against Pythium root rot, on either preventative or curative basis, unknown.
- REI: 12 h.
- FRAC Mode of Action: 28.

Benzimidazole

Thiophanate-methyl (Cleary's 3336, Fungo, Systec, Topsin)

- Efficacy: Good control of brown patch caused by *Rhizoctonia solani* but ineffective against leaf and sheath spot caused by *Rhizoctonia zeae*, which becomes more common on creeping bentgrass during hot weather. Excellent control of anthracnose diseases, dollar spot, and gray leaf spot. Cleary's 3336 is fairly effective in controlling brown patch.
- Resistance issues: This chemistry has a high risk of fungicide resistance development. Resistance in dollar spot populations is already widespread across the southeast, and resistance in anthracnose populations is developing rapidly. Resistance in gray leaf spot populations has not been documented but is expected due to the genetic variability within *P. grisea*.
- Other notes: L2 carcinogen.
- REI: 12 h.
- FRAC Mode of Action: 1.

Biological

***Bacillus licheniformis* SB3086 (EcoGuard)**

- Efficacy: Good control. Needs more research.
- REI: Not applicable.
- Other notes: Formulation contains significant amount of nitrogen, which amounts to approximately 1/8 lb N per 1000 ft^2 at 20 fl.oz. rate. Control of dollar spot may be a result of additional nitrogen. Ecoguard has been shown to enhance brown patch development, also likely due to nitrogen effect.

Carboxamides

Flutolanil (Prostar)

- Efficacy: Excellent control of basidiomycete fungi, including fairy rings, brown patch, and large patch. Very effective when applied in a preventive manner. It is effective in turf that has a history of brown patch. ProStar is a very important fungicide for controlling *Rhizoctonia*-induced diseases.
- Resistance issues: Resistance management is required.
- IPM issues: None noted.
- REI: 12 h.
- FRAC Mode of Action: 7.

Boscalid (Emerald, BAS 510F)

- Efficacy: Excellent control of dollar spot on preventative and curative basis.
- Resistance issues: None noted.
- Residual: Residual control of up to 14 days at low label rate and 21 days at high label rate.
- IPM issues: None noted.
- Other notes: One of few fungicides labeled for control of bentgrass dead spot. Systemic and translaminar movement.
- REI: 24 h.
- FRAC Mode of Action: 7.

Chlorophenyl (multi-site)

Chlorothalonil (Count Down, Daconil, Echo, Evade, Prograde)

- Efficacy: One of the few products that provides excellent control of algae invasions in putting green turf. These are important surface contact fungicides that are rotated with penetrant fungicides and have good efficacy for controlling brown patch.
- Resistance issues: Useful tool for managing fungicide resistance due to low resistance risk
- IPM issues: None noted.
- Other notes: Broad spectrum disease control, multi-site biochemical mode of action.
- REI: 48 h.
- FRAC Mode of Action: M5.

Demethylation inhibitor

Fenarimol (Rubigan)

- Efficacy: The most effective product for control of spring dead spot in bermudagrass.
- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Used most frequently for preemergence control of annual bluegrass. Not applied to cool-season grasses due to severe growth regulating effect
- REI: 12 h.
- FRAC Mode of Action: 3

Myclobutanil (Eagle)

- Efficacy: Applied by some turf managers for control of spring dead spot, although little research data is available to demonstrate that this product is effective.
- Resistance issues: pose medium risk for fungal resistance
- IPM issues: None noted.
- Other notes: May be phytotoxic on bermudagrass under high temperature when applied for control of leaf spot. Used primarily in spring and fall for control of dollar spot. Should not be applied to putting green turf during summer when high temperatures consistently exceed 90F due to growth regulating effects.
- REI: 24 h.
- FRAC Mode of Action: 3.

Propiconazole (Banner)

- Efficacy: Moderately effective for control of spring dead spot in bermudagrass, primarily on creeping bentgrass in spring, fall, and winter for dollar spot.
- Resistance issues: Poses medium risk for fungal resistance.
- IPM issues: None noted.
- Other notes: Phytotoxic when applied at high temperatures, therefore not used when temperatures are above 90 F. May increase sensitivity to frost injury in Fall and delay spring greenup.
- REI: 24 h.
- FRAC Mode of Action: 3.

Triadimefon (Bayleton)

- Efficacy: Bayleton is very important for controlling brown patch in home lawn situations.
- Resistance issues: Poses medium risk for fungal resistance.
- IPM issues: None noted.
- Other notes: Should not be applied to putting green turf when temperatures are expected to exceed 90F due to severe growth regulating properties.
- REI: 12 h.
- FRAC Mode of Action: 3.

Dicarboximide

Iprodione (Chipco 26 GT, Chipco 26019)

- Efficacy: Good to excellent preventative control of dollar spot and Helminthosporium leaf spots. Moderate to good brown patch activity. Chipco 26 GT is fairly efficacious in controlling brown patch of cool season turfgrasses.
- Resistance issues: medium to high risk exists for fungal resistance.
- IPM issues: None noted.
- Other notes: L2 carcinogen.
- REI: 12 h.
- FRAC Mode of Action: 2.

Vinclozolin (Curalan)

- Resistance issues: Medium to high risk of resistance.
- IPM issues: None noted.
- Other notes: Class C carcinogen.
- REI: When spray dries.
- FRAC Mode of Action: 2.

EDBC (=diethylbiscarbamate) (multi-site)

Mancozeb (Fore)

- Efficacy: One of the few products that provide excellent suppression of algae invasion in putting green turf. Also excellent for preventative control of Helminthosporium leaf spot diseases. These are important surface contact fungicides that are rotated with penetrant fungicides and have good efficacy for controlling brown patch.
- Resistance issues: Like chlorothalonil this is a useful tool for managing fungicide

resistance due to is low resistance risk.
- IPM issues: None noted.
- Other notes: Broad spectrum, multi-site biochemical mode of action.
- REI: When spray dries.
- FRAC Mode of Action: M3.

Thiram (Spotrete)
- REI: When spray dries.
- FRAC Mode of Action: M.

Zineb
- REI: When spray dries.
- FRAC Mode of Action: M.

Organophosphate

Fosetyl Al (Aliette) =Aluminum tris (O-ethyl phosphanate)
- Efficacy: Good to excellent preventative control of foliar Pythium diseases, but not effective on curative basis. Some activity against anthracnose basal rot in creeping bentgrass has been observed in field trials. Preventative efficacy against Pythium root diseases requires more research.
- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Beneficial effect on summer quality of creeping bentgrass when applied on regular intervals.
- REI: 12 h.
- FRAC Mode of Action: 33.

Phenylamide (multi-site)

Metalaxyl Mefenoxam (Subdue)
- Efficacy: Excellent preventative control of Pythium diseases. Best for curative control of Pythium diseases.
- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Often used in combination with ethazole products for curative control of Pythium root rot.
- REI: 12 h.
- FRAC Mode of Action: 4.

Phenylpyrrole

Fludioxonil
- Efficacy: Good for control of brown patch and yellow patch (cool-season brown patch). Excellent control of pink snow mold and Microdochium patch. One of few fungicides with demonstrated activity against bentgrass dead spot. Also some algae activity, Syngenta considering addition to label needs more research for gray leaf spot shows good efficacy.

- Resistance issues: None noted.
- Residual: Short-lived contact fungicide.
- IPM issues: None noted.
- REI: 12 h.
- FRAC Mode of Action: 12.

Phosphonates (multi-site)

Phosphorous acid (Alude, Resyst, Magellan, and Vital)

- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Needs much more research. Potential for foliar burn in creeping bentgrass when applied during very hot and/or dry weather.
- REI: 4 d.
- FRAC Mode of Action: M.

Polyoxin

Polyoxin D zinc salt

- Efficacy: Needs more research on Bipolaris leaf spot, melting-out and the crown and root rot stage but promises to be effective. Good control of brown patch. Excellent preventative control of anthracnose basal rot, but very poor curative activity, according to trials conducted on annual bluegrass in New Jersey. Excellent control of pink snow mold and Microdochium patch.
- Resistance issues: Medium risk of resistance.
- Residual: Short-lived contact fungicide.
- IPM issues: None noted.
- Other notes: Translaminar movement.
- REI: Not applicable.
- FRAC Mode of Action: 19.

QoI (strobilurins)

Azoxystrobin (Heritage)

- Efficacy: Preventive spray applications are effective for controlling brown patch in cool season turfgrasses.
- Resistance issues: high risk of fungicide resistance, resistance to azoxystrobin has been noted in some anthracnose (*Colletotrichum graminicola*) populations.
- IPM issues: A fairly low environmental impact fungicide.
- Other notes: Large spectrum of pest activity.
- REI: 4 h.
- FRAC Mode of Action: 11.

Trifloxystrobin (Compass)

- Efficacy: Needs more research for gray leaf spot. Preventive spray applications are effective for controlling brown patch in cool season turfgrasses.
- Resistance issues: A high risk of fungicide resistance.
- IPM issues: A fairly low environmental impact fungicide.

- Other notes: A large spectrum of pest activity.
- REI: 12 h.
- FRAC Mode of Action: 11.

Pyraclostrobin

- Efficacy: Shows excellent efficacy for *Rhizoctonia solani*, but needs more research for warm season grasses needs more research in perennial ryegrass, some in St. Augustinegrass for gray leaf spot. Preventive spray applications are effective for controlling brown patch in cool season turfgrasses.
- Resistance issues: High risk of fungicide resistance.
- IPM issues: A fairly low environmental impact fungicide.
- Other notes: A large spectrum of pest activity.
- REI: 12 h.
- FRAC Mode of Action: 11.

Substituted aromatic

PCNB quintozene (Engage, Revere)

- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Phytotoxic to cool-season grasses when temperatures exceed 70F. Should be applied only in late fall or early winter for preventative control of snow molds. May prove phytotoxic to warm season grasses when temperatures exceed about 85F.
- REI: ?
- FRAC Mode of Action: 15.

Chloroneb (Termec)

- Efficacy: Good in one Pythium blight study.
- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: Not commonly used.
- REI: Not applicable.
- FRAC Mode of Action: 14.

Thiazole

Etridiazole (Koban)

- Efficacy: Very effective for curative control of Pythium root rot in bentgrass, annual bluegrass, and bermudagrass putting greens.
- Resistance issues: None noted.
- IPM issues: None noted.
- REI: 12 h.
- FRAC Mode of Action: 14.

Multiple a.i. formulation

Mancozeb+copper hydroxide

- Efficacy: Excellent control of algae in putting green turf. Needs more research for gray leaf spot.
- Resistance issues: None noted.
- IPM issues: None noted.
- Other notes: May injure turf due to short term effects (direct foliar burn) or long-term effects (accumulation of copper to toxic levels). Recommended only for curative control of severe algae infestations for this reason.
- REI: 48 h.
- FRAC Mode of Action: M3 + M2.

Key Pest-by-Pest Profiles and Critical Issues:
Weeds, Algae and Mosses

WEED MANAGEMENT

Because weeds compete for space, water, nutrients and sunlight, turfgrasses, like most other crops, are sensitive to competition. Healthy turf is most effective in providing competition to weed infestations. Therefore season-long weed management is influenced by disease, insect, fertility and irrigation management. However, the issues which contribute most to weed management decisions are aesthetics and safety (for sport fields). Differing turfgrass situations will have varying tolerance to weed presence. For example, putting greens have a zero-tolerance for weed species, whereas, a moderate infestation of weeds is quite acceptable in a park or recreation area.

Turfgrass managers must contend with a variety of annual and perennial broadleaf and grassy weeds in the Southern Region states. The most problematic weeds in the Southern Region are purple nutsedge followed in importance by crabgrass, goosegrass, yellow nutsedge and common bermudagrass. Spotted spurge, henbit, chickweed species, bahiagrass, dallisgrass, annual bluegrass, lawn burweed, and Virginia buttonweed are intermediate level pests, while pigweed prostrate knotweed, plantains, and dandelion are regarded as less problematic. There are also some commercial turfgrasses that have weed potential, such as bermudagrass, zoysiagrass and tall fescue. A composite list of the major weed species influencing the Southern region will be described below. However, the total spectrum of current and potential weeds can not be covered.

Although many herbicides are labeled for turfgrass in general, often the most expensive ones used on golf courses and other professional turfgrass areas are not used in commercial sod. Because many more herbicides are available to turfgrass managers licensed as commercial applicators, the spectrum of herbicidal active ingredients used in commercial, recreational and golf course turf exceeds those used by homeowners.

With a closely followed preemergence herbicide program, postemergence herbicides are used less frequently. Also, many factors can affect preemergence herbicidal activity such as organic matter and soil texture. Preemergence herbicides should be applied before soil temperatures reach 55 F^0 at a 4-inch depth for 2 to 3 days. Preemergence herbicides should receive 0.25 to 0.5 inches of water through rainfall or irrigation to move the herbicide into the soil. Most preemergence herbicides have a half life of 60-75 days and often require two applications to provide season long control. Postemergence herbicides are most effective when applied to young actively growing weeds. Some postemergence herbicides when applied when air temperatures are above 85-90 F^0 can cause phytotoxicity to the turf.

Control of crabgrass species and goosegrass still represents the vast majority of pre-emergence herbicide use in turfgrass. Preemergence herbicides for crabgrass and goosegrass represent approximately 60% of all herbicide use in commercial turf. Postemergence herbicides are also utilized for remedial crabgrass and goosegrass control on approximately 10% of turfgrass acreage. These are utilized when preemergence herbicide activity is inadequate, or when weed species not controlled by preemergence herbicides are present.

Weeds can be categorized by their biological characteristics which can determine herbicide selection. Weeds are grouped either as summer or winter germinating annuals, biennials and perennials, and further into three major classes: grasses, grass-like (sedges) or broadleaf weeds. Preemergence herbicides are commonly used to control certain winter and summer annual weed species. For selective *postemergence* herbicides, control tends to follow the

major classes of weeds and weed families. Some herbicides control grasses, while others control broadleaf weeds.

Due to limited cultural control methods such as crop rotation and cultivation, herbicides will remain in the forefront of turfgrass weed control. However, every effort should be made to use no more herbicide than necessary to obtain acceptable weed control for a given situation.

MAJOR CLASSES OF WEEDS

Annual weeds

- **Sub-divisions:** Summer annuals and winter annuals, and further into broadleaf versus grass and grass-like weeds.
- **Life cycle:** Annual weeds complete their life cycles in one season by flowering, maturing seed, and dying. Summer annual weeds flower in the summer, produce seed in mid-to late summer, and either die in the fall or are killed by frost. Winter annuals have an opposite life cycle.
- **Reproduction:** High seed production serves as a ready source for infestation when conditions are favorable. Summer annual weeds germinate from late March through July, depending on the location. Mid-summer rains frequently encourage germination. Winter annual weeds germinate in the fall.
- **General control measure(s):** easiest to control of the three main weed life cycles (annual, biennial, perennial)

Biennial weeds

- **Sub-divisions:** None (all biennials are broadleaf weeds).
- **Life cycle:** Biennial weeds require two growing seasons to complete their life cycles. They germinate and form a low growing rosette of leaves in the summer or fall of one year and grow a tall flower stalk in the second year. After producing seed the second year, they die.
- **Notes:** Biennials can be a problem in their first or second year.
- **Reproduction:** Biennials reproduce by seed in their second year.
- **General control measure(s):**
    - Biennials can be controlled by a number of different preemergence and postemergence herbicides.
    - Most growers rely on postemergence herbicides to kill or suppress the weeds before they produce flower stalks.
    - Most are readily controlled by glyphosate.
    - Clopyralid, a selective postemergence herbicide is particularly effective on thistles, but is not effective on Queen Anne's lace or mullein.

Perennial weeds

- **Sub-divisions:** Grass, grass-like, broadleaf.
- **Life cycle:** Perennial weeds live two or more years. Many herbaceous weeds die back to their tubers, bulbs, stolons, or storage roots over the winter.
- **Reproduction:** Have diverse means to reproduce and survive over the winter. Some creeping species grow horizontally by way of above-(stolons) or below-ground (rhizomes) stems. Others form tillers, which contribute to a bunch-type growth habit. Still

others have corms, tubers, bulbs or thick tap roots. Each year, many perennial weeds produce large amounts of viable seeds and may produce seed each season.

- **Notes:** With the differing means of storing energy from year to year, and once established and mature, perennial weeds are often very difficult to control.
- **General control measure(s):**
    - Preemergence herbicides are important in controlling the germination of perennial seedlings.
    - Where perennials are already established, postemergence herbicides are necessary.
    - Most perennials are kept in check by postemergence herbicide applications.
    - Postemergence herbicides (e.g. 2,4-D, MCPP, dicamba, fenoxaprop-p-ethyl, quinclorac, MSMA, metsulfuron and triclopyr + clopyralid) can be used to provide effective selective control of numerous emerged perennial weed species in turfs.
    - Virtually all perennial weed problems can be addressed through a complement of non-selective herbicides although, due to potential turfgrass injury, most managers use selective postemergence herbicides.

Summer annual broadleaf weeds

General IPM and/or management issues:

- If inadequately managed, dense stands of summer annual broadleaf weeds can provide intense competition to turfgrasses.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Education and research on the timing of preemergence and postemergence herbicides

Control Measures recommended and used:

Cultural/mechanical: Maintain a healthy, dense turf.

Biological: No biological control options are currently available for use

Chemical:

- The majority of summer annual broadleaf weeds can be kept in check with postemergence herbicides. While the weeds may not die, height, density, and the amount of seed are reduced. Postemergence herbicide effectiveness can vary from season to season if growers do not pay attention to the timing of initial summer annual weed germination.
- Trimec (2,4-D + MCPP + Dicamba) or other combination products are often used on established sod as well as other combination products.
- Buctril is often selected for postemergence weed management of young broadleaf seedlings on newly emerged turfgrass.

Pest Name (common, scientific): Prostrate knotweed (*Polygonum caespitosum* L.), **common lespedeza** [*Kummeronia striata* (Thumb.) Schindler], **pigweed** (*Amaranthus* spp.), **prostrate**

spurge (spotted sandmat, *Chamaesyce maculata* (L.) Small) and **spotted spurge** (hyssopleaf sandmat, *Chamaesyce hyssopifolia* L.).

Description, distribution, importance and control measures used and recommended for each weed

Prostrate Knotweed

Description: Tough, wiry, slender stems radiate from a central taproot and produce a tough mat-like growth. Leaves are dull, blue-green, oblong to linear in shape, smooth, and alternate with a membrane at the base sheathing the stem. Newly emerging seedlings are often mistaken for grasses in very early stages of development.
Reproduction: Seed.
Distribution within Southern region: Throughout.
Notes:

- Can survive close mowing because of prostrate growth habit.
- A very competitive weed in infertile and compacted soils and often invades turfgrasses along driveways, sidewalks, and beaten paths across lawns.
- One of the first summer annuals to germinate in the spring.

Common Lespedeza

Description: Dark green and wiry with trifoliate leaves. Several wide-spreading prostrate branches come from the slender taproot. Hairs grow downward on the stem. Stipules are light to reddish brown. Small single flowers arise from the leaf axils on most of the nodes of the main stems and are pink or purple.
Reproduction: Seed.
Distribution within Southern region: Throughout.
Notes:

- Commonly found in soils with low fertility.
- Can survive close mowing because of prostrate growth habit.
- A very common summer weed, choking out thin turf.
- Use a postemergence herbicide during seedling to flower stage when lespedeza is actively growing.

Pigweed

Description: Tall with erect, smooth to hairy stems. Petioles long. Leaf blades oval with a sharp tip. Male and female flowers mixed in clusters in leaf axils and in large terminal panicles.
Reproduction: Seed.
Distribution within Southern region: Throughout.
Notes: Found in fields, moist areas, roadsides and disturbed areas.

Prostrate Spurge (spotted sandmat)

Description: Branches freely from the crown of a thick taproot. When the stems are broken they emit a milky juice. The leaves are opposite and vary in color from a pale reddish-green to a dark green but usually have a conspicuous maroon blotch. The leaves are smooth or

sparsely hairy, toothed especially near the tip and unequally sided at the base with a short petiole. Flowers are very small, pinkish-white, inconspicuous, and borne in the leaf axils.
Reproduction: Seed contained in a three-lobed capsule that develops rapidly.
Distribution within Southern region: Throughout.
Notes:

- Prostrate spurge may flower within three to four weeks after emerging in mid-summer. The mat-like growth often chokes out desirable turfgrasses.
- Can tolerate compact soils and is often found in high-traffic areas; therefore, core-aerate and divert foot traffic if possible.
- Use a preemergence herbicide to prevent spurge germination. Use a postemergence broadleaf herbicide as needed to control spurge Make herbicide applications when spurge is actively growing in the four-leaf to flower stage of growth.

Spotted spurge (hyssopleaf sandmat)

Description: Small with freely branched prostrate stems that do not root at the nodes. Stems smooth or hairy, with "milky" sap. Leaves opposite, usually with a reddish spot, not symmetrical. Prostrate spurge (*Chamaesyce maculata* (L.) Small) is similar but roots at the nodes.
Reproduction: Seed.
Distribution within Southern region: Throughout.
Notes: Occurs in any disturbed area.

Summer annual grasses

General IPM and/or management issues: Annual grasses pose a problem because of their vigorous growth, competitive nature, and ability to produce copious amounts of seed. All annual grasses should be controlled before seed set. If inadequately managed, dense stands of summer annual grasses can become extremely thick in just a few weeks. Many summer annual grasses follow a similar pattern of development and timing of treatment as summer annual broadleaf weeds. Weed growth must be monitored and treatment timings adjusted accordingly.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: Increased efforts to find control of crabgrass in St. Augustinegrass turf.

Control Measures recommended and used:
Cultural/mechanical: Maintain a healthy, dense turf.
Biological: No biological control options are currently available for use
Chemical:

- Annual grasses can be controlled by several preemergence herbicides.
- Postemergence herbicides are most effective when applied to young actively growing grasses.
- Some postemergence herbicides when applied when air temperatures are above 85-90F can cause phytotoxicity to the turf.
- Preemergence herbicides should be applied before soil temperatures reach 55F at a 4-inch depth for 1 to 3 days.

- Preemergence herbicides should receive 0.25 to 0.5 inches of water from rainfall or irrigation to move the herbicide into the soil and after the application to maximize control. Most preemergence herbicides have a residual activity of 60-75 days and often require two applications to provide season long control.

Description, distribution, importance and control measures used and recommended for each weed

Pest Names (common, scientific): Large crabgrass [*Digitaria sanguinalis* (L.) (Scop)], **smooth crabgrass** [*Digitaria ischaemum* (Schreb.) Muhl.], **southern crabgrass** [*Digitaria ciliaris* (Retz.) Koel.] and **goosegrass** [*Eleusine indica* (L.) Gaertn.].

Large Crabgrass
Smooth Crabgrass
Southern Crabgrass

Description: Tufted, or prostrate to spreading with branched stems that root at the nodes. Leaf blade, longer than 2 inches (5 cm), usually hairy on both surfaces, visible toothed membranous ligule at base of leaf. Leaf sheath with dense hairs. Smooth crabgrass plants lack hairs except for a few long hairs at the collar. Spikelets in two to nine finger-like branches.

- Southern crabgrass is distinguished from large crabgrass on the basis of the length of the second glume (a bract at the base of a spikelet). These species differ from tropical crabgrass in that the seedhead branches arise from different points of attachment along the stalk.
- Crabgrass germinates from March through early May when soil temperatures reach 53ºF to 58ºF near the soil surface. Alternating dry and wet conditions at the soil surface in the spring encourages germination.

Reproduction: Seed, may root at lower nodes

Distribution within Southern region: Smooth and Southern crabgrass, throughout, west to Texas; Large crabgrass throughout, except Florida.

Notes: Will grow under close mowing conditions.

- Maintain a dense, actively growing turf, as crabgrass competition is enhanced by thin, open turfgrass stands; improper mowing heights for the desired turf; summer fertilization; and light, frequent irrigation.
- Crabgrass control is extremely difficult in St. Augustinegrass turf.
- In areas where there is a crabgrass history, apply a preemergence herbicide in the spring. A second preemergence treatment eight weeks after the initial application may be necessary to maintain season-long control of crabgrass. Arsenical herbicides (DSMA, MSMA, CMA), Drive, Vantage or Acclaim Extra may be applied postemergently for control of emerged crabgrass early in the summer in certain turfgrasses.
- Preemergence herbicides for crabgrass are the most commonly used products. These include dinitroanilines (DNAs) such as pendimethalin (Pendulum, Pre M), prodiamine (Barricade), benefin + trifluralin (Team Pro), oryzalin (Surflan). Two other commonly used preemergence herbicides that are not DNAs are oxadiazon (Ronstar) and dithiopyr (Dimension).
- Preemergence crabgrass products are not generally used in sod production since they can inhibit root development of immature turfgrasses. Products such as Acclaim Extra and MSMA can be used if it becomes necessary. A new product on the market, Drive, is

showing excellent results for postemergence crabgrass control in both young and mature turfgrasses.

Goosegrass

- **Description:** Tough, clumped generally with a "whitish to silverish" coloration at the center of the plant. Leaf blade smooth on both surfaces, occasionally a few hairs near the base. Visible, short-toothed, membranous ligule at base of leaf blade. Spikelets in two rows on two to thirteen fingers. Frequently a single finger below the terminal cluster of fingers. Goosegrass germinates when soil temperatures reach 60^{o}F, which is usually at least two weeks later than crabgrass. Like crabgrass, it requires moisture and light for germination; however, it is very competitive in compacted soils.
- Goosegrass has a prostrate growth habit, but unlike crabgrass it does not root at the nodes.
- It competes very successfully with warm-season turfgrasses during summer months and is most competitive in thin, open turfs subject to intense traffic or use. Close mowing, frequent watering, and compaction enhance goosegrass competition.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:**
    - A severe goosegrass infestation may indicate the need for aerification to alleviate compaction.
    - Preemergence herbicides used for crabgrass control are commonly less effective on goosegrass.Goosegrass may also be controlled by postemergence application of an arsenical herbicide mixed with Sencor in bermudagrass, Acclaim Extra, Revolver and Vantage.

Perennial grass weeds

General IPM and/or management issues: Due to the lack of selective herbicides, many perennial grasses are difficult to control in turfgrasses.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: Development of selective herbicides.

Control Measures recommended and used:

Cultural/mechanical: Maintain a healthy, dense turf.

Biological: No biological control options are currently available for use.

Chemical: Few options available due to a lack of selective herbicides.

Description, distribution, importance and control measures used and recommended for each weed

Pest Names (common, scientific): Bahiagrass (*Paspalum notatum* Fluegge), **dallisgrass** (*Paspalum dilatatum* Poir.), **field paspalum** (*Paspalum laeve* Michx.) and **thin (or bull) paspalum** (*Paspalum setaceum* Michx.).

Bahiagrass

- **Description:** Aggressive, mat-forming, with shallow, often-exposed rhizomes. Leaves, primarily basal, somewhat folded, smooth on both surfaces or often hairy only at the collar. Ligule short, membranous. Seedheads with usually two or occasionally three branches. Easily recognized by the characteristic "V" shape of the seedhead. Spikelets in two rows on lower sides.
- **Reproduction:** Seed and rhizomes.
- **Distribution within Southern region:** Common throughout.
- **Notes:**
    - Widely planted and maintained on roadsides and highway rights of way. It is well suited for roadsides because of its good drought tolerance and general competitive ability in the southern United States. Unfortunately, it can be very competitive and unsightly in highly maintained turf.
    - As with other perennial paspalums, bahiagrass can be difficult to control. Manor (metsulfuron) is a newer herbicide that can be used in all warm-season turf species to selectively remove bahiagrass. Repeat applications of organic arsenicals can be used in tolerant turfgrasses.

Dallisgrass
Field Paspalum
Thin (or Bull) Paspalum

- **Description:** Clumped perennials which from short thick rhizomes. Leaf sheaths at base of plant sometimes rough hairy. Leaf blade, smooth on both surfaces, with a few long hairs at leaf base and behind ligule at base of leaf blade. Ligule tall, membranous, either sharply or bluntly tipped. Depending on the species, spikelets are arranged in four rows on three to seven alternate branches.
- **Reproduction:** Seed and very short rhizomes.
- **Distribution within Southern region:** Common throughout.
- **Notes:**
    - These paspalum species resemble each another very closely, and field paspalum and thin paspalum are often mistakenly called dallisgrass. They are common and are some of the more difficult-to control weeds in turfgrasses.
    - One proven way to selectively remove this group of paspalums is multiple applications of arsenical herbicides in the early spring and summer on tolerant turfgrass species only.

Perennial broadleaf weeds

General IPM and/or management issues: Perennial broadleaf turf weeds are capable of living more than two years. They are primarily spread by seed, which are produced in the spring or early summer. Many are capable of vegetative reproduction, which makes them difficult to control.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Control Measures recommended and used:

Cultural/mechanical: Maintain a healthy, dense turf.

Biological: No biological control options are currently available for use

Chemical:

- Two-way and three-way herbicide mixtures that contain 2,4-D, MCPP, dicamba, fluroxypyr and triclopyr are often used on established sod as well as other combination products.

Description, distribution, importance and control measures used and recommended for each weed

Pest Name (common, scientific): Broadleaf plantain (*Plantago major* L.), **buckhorn plantain** (*Plantago lanceolata* L.), **curly dock** (*Rumex crispus* L.), **dandelion** (*Taraxacum officinale* Wiggers), **Carolina dichondra** (*Dichondra carolinensis*), **Florida betony** (Rattlesnake weed, *Stachys floridana* Shuttlew.), **indian mockstrawberry** [*Duchesnia indica* (Andr.) Focke], **Virginia buttonweed** (*Diodia virginiana* L.), **white clover** (*Trifolium repens* L.), **wild garlic/onion** (*Allium vineale* L./*A. canadense* L.) and **yellow woodsorrel** (*Oxalis stricta* L.).

Broadleaf Plantain

- **Description:** Perennial with a distinctive rosette of leaves, and slender, fibrous root system. Leaves broad, egg- shaped, with several main veins. Erect, leafless stems terminate in dense, flower spikes.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Blackseed plantain (*Plantago rugellii* Dcne.) is similar except stems and petioles longer and leaves somewhat larger.

Buckhorn Plantain

- **Description:** Distinctive rosette of leaves and a slender, fibrous root system. Leaves are basal, long and narrowly elliptic to lance-shaped, often twisted or curled, with ribbed with several prominent parallel veins on lower leaf surface. Erect, leafless, hairy stalk terminated by dense, tapered, white to tannish flower spike. As it blooms, the stamens are exerted from the spike.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Very common throughout region.
- **Notes:** Found in poorly managed turfgrasses.

Curly Dock

- **Description:** Perennial with mostly basal leaves up to 12 inches long. Leaves often have wavy or curly margins and may be tinged with reddish purple. Small greenish flowers are produced in clusters at the top of the main stems. Flowers become reddish-brown at maturity. Shiny, reddish-brown triangular seed is surrounded by three sepals.
- **Reproduction:** Seed.

- **Distribution within Southern region:** Throughout.
- **Notes:** Curly dock seldom produces seed in maintained turf. Has a thick, fleshy taproot.

Dandelion

- **Description:** Leaves grow in a rosette from the crown. They are long, irregularly lobed, lightly to deeply cut, and lance shaped. The lobed tips are often opposite each other and pointing toward the crown. Leaves are often purple at the base and flower stalks exude a "milky" juice/latex when broken. Deep golden single yellow flowers at end of each long, smooth hollow stalk soon mature into spherical clusters of whitish fruits, like white puffballs, composed of parachute-like seeds.
- **Reproduction:** Wind dispersed seed. Can form new plants from fragments of broken taproots.
- **Distribution within Southern region:** Throughout.
- **Notes:** Hardy with a thick, fleshy taproot and no stem.

Carolina Dichondra

- **Description:** Prostrate perennial with kidney-shaped to nearly circular alternate leaves. White to greenish small flowers are borne in clusters in the leaf axils below the level of the leaf. Forms mats 1 to 3 inches tall.
- **Reproduction:** Spreads by slender creeping stems that root at the nodes, and seeds.
- **Distribution within Southern region:** Throughout.
- **Notes:** Dichondra is cultivated as a ground cover and even as a lawn replacing turfgrass in some states.

Florida Betony

- **Description:** Has square stems and produces white to pink flowers in the spring. Easily recognized by the very characteristic white tuber that resembles a rattlesnake rattle.
- **Reproduction:** Primarily by tubers, secondarily by seed.
- **Distribution within Southern region:** found throughout region and west to Texas.
- **Notes:** Hard-to-control perennial weed that emerges in the fall and becomes a problem in late winter and spring.

Indian Mockstrawberry

- **Description:** Leaves are alternate and trifoliate. Leaflets are toothed and hairy with long, hairy petioles with leaf-like stipules. Single flowers with five yellow petals are borne on long stalks from the leaf axils. The fruit is red and fleshy and similar in appearance to the commercial strawberry though smaller and tasteless.
- **Reproduction:** Spreads by stolons and seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Prefers semi-shaded areas.

Virginia Buttonweed

- **Description:** Prostrate or spreading with, longitudinally ridged, hairy branched stems. Leaves opposite, elliptic to lance-shaped, sessile, joined across stem by membrane. Membrane with a few "hair-like" projections. The leaves are slightly thickened, green on

the upper surface and light green on the lower surface with both surfaces smooth and slightly folded, often with a mottled-yellow mosaic look. White tubular flowers with four lobes at each leaf axil along the stem. Flower usually with only two sepals. Fruit green, elliptically shaped, hairy, ridged and at each leaf axil.

- **Reproduction:** Seed, roots and stem fragments.
- **Distribution within Southern region:** Throughout.
- **Notes:** Favors moist to wet sites, therefore it is important to ensure a well drained and aerated turf. This is considered one of the most troublesome weeds in turfgrasses.

White Clover

- **Description:** Leaves have three leaflets with a long erect petiole. Leaves are widely ovate with usually a white crescent-shaped mark near the base of the upper surface of each leaflet. The flowering heads are borne on long stalks arising from the stems and usually above the leaves. The flower cluster may be 1/2 to 1 1/2 inches in diameter. The petals are white or occasionally tinged with pink.
- **Reproduction:** Creeping stems and seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Common in areas of low N fertility.

Wild garlic/onion

- **Description:** Slender, hollow cylindrical leaves which occur on the flowering stem up to half the height of the plant. Underground bulb bears offset bulblets that are flattened on one side and enclosed by a membrane. Flowers, greenish-white, small, on short stems above aerial bulbils.
- **Reproduction:** Seed, aerial bulbils and underground bulblets.
- **Distribution within Southern region:** Throughout most of the eastern and southern United States, west to Missouri and Arkansas.
- **Notes:** Distinctive garlic odor when crushed. Wild onion (*Allium canadense* L.) is often found on same sites as wild garlic. Wild onion can be distinguished from wild garlic by presence of a fibrous coat on the central bulb, no offset bulblets and leaves that arise near the base of a solid flowering stem.

Yellow Woodsorrel

- **Description:** Stems are hairy and 4 to 10 inches tall. Leaves are alternate and divided into three leaflets. The leaflets are heart-shaped and partly folded. Two to nine flowers are formed together with each being bright yellow with five petals about 3/8 inch long. The fruit is a narrow capsule 1/2 to 1 inch long on bent stalks just below the capsule.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Supported by a shallow taproot and sometimes has very short stolons. Typically occurs in low maintenance turf areas.

Sedges & Kyllinga

General IPM and/or management issues: Sedges are weeds that resemble grasses but unlike grasses, sedges have three-sided or triangular stems. The stem shape can be observed by

removing the plant from the soil and cutting the stem in cross section at or slightly above the soil line. Many sedge species thrive in wet or poorly drained soils but can survive in areas that are not wet. Because of frequent irrigation in highly maintained turf, sedges often thrive in the turfgrass environment. Proper identification and an understanding of the biology of sedges is necessary for effective management. Most of these species are perennials and represent some of the more difficult weeds to control. However, a few species (particularly annual sedges) can be easily controlled. In addition, there are several new species of sedges (*Kyllinga* spp.) that are spreading rapidly in many areas. Because many sedges can only be identified by their respective seedheads and because repeated mowing often prevents seedhead development, it may be necessary to remove the sedge from the managed turfgrass area and allow seeds to develop in a greenhouse or other similar-type environment. As a general rule, sedges are more of a problem in warmer climates than cooler climates.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Control Measures recommended and used:

Cultural/mechanical:

- Maintain a healthy, dense turf. Do not over-irrigate and install drainage systems in wet soils.

Biological: No biological control options are currently available for use.

Chemical:

- Nutsedge control is accomplished with Certainty, Manage, Monument, Basagran T/O, Image and organic arsenical herbicides.
- The overwhelming majority of turfgrass preemergence herbicides do not control sedges. Triazine herbicides (e.g., atrazine, simazine) provide fair preemergence control of some annual sedges but are ineffective on perennial species.
- Metolachlor (Pennant) provides preemergence control of most annual sedges and yellow nutsedge. However, purple nutsedge is not controlled by metolachlor. Pre-emergence control of purple nutsedge is currently unavailable.
- Historically, postemergence chemical control of most sedges was attempted with repeat applications of 2,4-D, the organic arsenicals (MSMA, DSMA) or a combination of the two.
- Although organic arsenicals were effective, numerous applications over a period of years generally were necessary. Extensive damage also resulted with certain turf species, such as centipedegrass and St. Augustinegrass.

Pest Name (common, scientific): Annual sedge (*Cyperus compressus* L.), **green kyllinga** (*Kyllinga brevifolia* Rottb.), **false green kyllinga** (*Kyllinga gracillima* Miq.), **globe sedge** (*Cyperus croceus* Vahl.), **purple nutsedge** (*Cyperus rotundus* L.) and **yellow nutsedge** (*Cyperus esculentus* L.).

Description, distribution, importance and control measures used and recommended for each weed

Annual Sedge

- **Description:** Annual sedge with clusters of flat spikes on short to long stalks. Annual sedge tends to have a "clumpy" appearance - particularly when it occurs in low densities.
- **Reproduction:** Seed.
- **Distribution within Southern region: T**hroughout.
- **Notes:**
    - This species is one of the few sedge species that is a true annual. As a result, this sedge is easier to control than many other perennial sedges. Tends to emerge later in the spring/summer than most other sedge species.
    - Several preemergence crabgrass herbicides will partially control this weed. However, effective control usually involves postemergence applications of various herbicides.

Green Kyllinga
False Green Kyllinga

- **Description:** both are mat-forming perennials and have well-developed rhizomes. They tend to be shorter growing and have a finer leaf texture than other sedges.
- **Reproduction:** Rhizomes and seed.
- **Distribution within Southern region:** Spreading rapidly in turfgrasses in the southern United States.
- **Notes:**
    - These two species are very similar in appearance and both are referred to as green kyllinga. They tend to thrive under close mowing (1/2 inch or less) and are very prolific in areas that are poorly drained or frequently wet. Green kyllinga is very difficult to control once the large mats form. Because *K. gracillima* is found in cooler climates, it is assumed this species is more cold tolerant than *K. brevifolia*. It is believed that spread of these two species may be due to a change in crabgrass control practices in recent years.
    - Preemergence crabgrass herbicides offer no control of these two species, whereas arsenical herbicides have significant activity. Therefore, when the arsenical herbicides were regularly used for crabgrass control, these two sedge species were probably controlled. Current control recommendations include multiple applications of arsenical herbicides in tolerant turfgrasses. Herbicides used to manage this species include: Manage, Certainty, Monument, organic arsenicals, Image and Basagran T/O.

Globe Sedge

- **Description:** A perennial that form seed in loose globe-like clusters.
- **Reproduction:** Seed.
- **Distribution within Southern region:** From Virginia south into Florida and west to Texas, Oklahoma, and Missouri.
- **Notes:**
    - Care should be taken to prevent this sedge from producing seed.
    - As with other perennial sedges, multiple herbicide applications are usually necessary for effective control. Herbicides used to manage this species include:

Pennant, Manage, Monument, Certainty, Image, Basagran T/O and organic arsenicals.

Purple nutsedge

- **Description:** Rapidly-spreading perennial with three-ranked basal leaves. Leaves flat or slightly corrugated, usually shorter than flowering stem, abruptly tapering at tip. Seedhead purple to reddish brown, formed at end of triangular stem. Tubers, oblong, covered with hairs, and found in chains connected by brown, wiry rhizomes.
- **Reproduction:** Primarily by tubers.
- **Distribution within Southern region:** Found north to Kentucky and West Virginia, west to Central Texas.
- **Notes:**
    - Not as cold tolerant as yellow nutsedge, and therefore tends to be more of a problem in warm-season turf. As with yellow nutsedge, control strategies must begin in the spring after maximum shoot emergence but before new tuber production. This species is much more difficult to control than yellow nutsedge.
    - *Distinguishing between yellow and purple nutsedge:*
        1. Purple nutsedge produces tubers in chains connected by rhizomes, whereas yellow nutsedge only produces tubers at the tips of rhizomes.
        2. Purple nutsedge tends to have darker green leaves and produces a characteristic reddish-purple seedhead.
    - Effective management will require multiple herbicide applications per year and will likely require several years to successfully control heavy infestations.
    - No preemergence herbicides are available to control this weed. Post emergence herbicides used are Manage, Monument, Certainty, Image and organic arsenicals.

Yellow nutsedge

- **Description:** Rapidly spreading perennial with three-ranked basal leaves. Leaves flat (grass-like) or slightly corrugated, usually as long as or longer than flowering stem, with long attenuated tip. Seedhead yellowish-brown or straw colored, formed at end of triangular stem. Tubers round, lacking hairs and formed at ends of whitish rhizomes. Tubers do no form chains.
- **Reproduction:** Primarily by tubers.
- **Distribution within Southern region:** Throughout.
- **Notes:** One of the more cold-tolerant sedge species. Proper identification is important to obtain effective control. Timing of control strategies is also important. Postemergence control strategies should begin in the spring after maximum shoot emergence but before new tuber production.
- Control with preemergence applications of Pennant, or postemergence use of Basagran T/O, Image, Monument, Certainty and organic arsenicals.

Winter annual weeds

- Winter annuals germinate in the fall and early winter and usually die with warm weather in the spring or earlysummer.
- Overwinter as small seedlings.

- In some warmer areas they may grow throughout the winter but are somewhat dormant during winter in northern regions of the transition zone.
- Winter annuals undergo rapid growth in early spring and usually die with warm weather in late spring or early summer when temperatures exceed 80 F.
- Control can be achieved with selected preemergence and postemergence herbicides.
- As the soil temperatures cool below 80-75 F many of these weeds will germinate in the presence of adequate soil moisture.
- Timing of properly selected preemergence herbicides should precede the temperature threshold by 1-3 weeks.
- Preemergence herbicides include: triazines (atrazine and simazine), benefin, bensulide, dithiopyr, oryzalin, pendimethalin, prodiamine and isoxaben.
- Postemergence control of these species should occur prior to reaching the 4th leaf stage.

Winter annual broadleaf weeds

General IPM and/or management issues: Warm-season turfgrasses are readily infested with winter annual broadleaf weeds. Many have a prostrate growth habit and are not affected by mowing. Control for many of these weeds will depend on the proper selection and timing of preemergence herbicides.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues:

- Education and application timing of herbicides.

Control Measures recommended and used:

Cultural/mechanical: Maintain a healthy, dense turf.

Biological: No biological control options are currently available for use.

Chemical:

- Timing of properly selected pre-emergence herbicides should precede the temperature threshold by 1-3 weeks.
- Post emergence control of these species should occur prior to reaching the 4th leaf stage.
- Combination products that contain 2,4-D, MCPP, dicamba, fluroxypyr, clopyralid or thriclopyr are used on established turfgrasses.
- Buctril is often selected for post-emergent weed management of young broadleaf seedlings on newly emerged turfgrass seedlings.
- Triazines such as atrazine, simazine and metribuzin also control numerous winter annual broadleaf weeds in tolerant turfgrass species.

Pest Names (common, scientific): Buttercups (*Ranunculus* spp.), **Carolina geranium** (*Geranium carolinianum* L.), **common chickweed** [*Stellaria media* (L.) Cyrillo], **mouseear chickweed** (*Cerastium vulgatum* L.), **corn speedwell** (*Veronica arvensis* L.), **hairy bittercress** (*Cardamine hirsuta* L.), **henbit** (*Lamium amplexicaule* L.), **parsley-piert** [*Aphanes microcarpa* (Boiss. and Reut.) Rothm.] and **spurweed or lawn burweed** (*Soliva sessilis* Ruiz & Pavon).

Description, distribution, importance and control measures used and recommended for each weed

Buttercups

- **Description:** leaves are attached to long petioles, palmately three-lobed and hairy. Flowers consist of five-parted pale yellow petals 5 to 9 mm in length. The seed are flattened with rings of knobby projections (tubercles) on the flattened surfaces, and have curved, hooked, or straight beaks on the tips. Hairy buttercup has erect, hairy stems (single or branching from the base) and a fibrous root system.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.

Carolina Geranium

- **Description:** The leaves are deeply 5- to 7-lobed and each lobe is again lobed and bluntly toothed. The flower is pink to lavender and borne two to several together on stalks from the upper nodes.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Also called cranesbill because the fruits have a conspicuous "cranesbill" beak about 1/2 inch long. Flowers mostly in April and May.

Common Chickweed

- **Description:** Mat forming with a weak, shallow root system and numerous branched stems. Leaves are opposite, oval to broadly elliptic in shape. Stems have vertical lines of hairs. Small white flowers are borne in clusters at the end of the stems. Flowers have five deeply notched petals and, though small, the flowers are quite noticeable.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:** Often forms extensive, dense patches which impede turf growth.

Mouseear Chickweed

- **Description:** Vigorous prostrate growth habit. Leaves of mouseear chickweed are opposite, oblong, dark green and, in contrast to common chickweed, covered with soft hairs. The small, white flowers have five slightly notched petals.
- **Reproduction:** Seeds, also roots at nodes.
- **Distribution within Southern region:** Throughout.
- **Notes:** Acts as a winter annual south of the transition zone.

Corn Speedwell

- **Description:** The lower leaves of corn speedwell are rounded and toothed, while the upper leaves are smaller and more pointed. The entire low-growing plant is covered with soft, fine hairs. The flowers are small, bright blue with white throats, and nearly stalkless. The seedpods are heart-shaped.
- **Reproduction:** Seed and stem fragments.
- **Distribution within Southern region:** Throughout.
- **Notes: T**hrives in thin open turf and often appears in solid stands.

Hairy Bittercress

- **Description:** Leaves are mostly on the lower portion of the stem in a basal rosette, deeply lobed, bearing a few minute hairs at the base of the leaf and occasionally on the upper surface of the leaf. Flowers are borne in dense clusters at the end of branches and are small with four white petals. The fruit, which is a capsule, develops rapidly and is about 3/4 inch long and 1/32 inch wide.
- **Reproduction: S**eed.
- **Distribution within Southern region:** Throughout.

Henbit

- **Description:** Sparsely-hairy with greenish to purplish tender four-sided stems. Leaves are opposite, rounded, with bluntly toothed margins, sparsely-hairy, and have prominent veins on underside. The upper leaves are sessile or clasp the stem. Reddish-purple flowers are in whorls in the axils of the upper leaves. Petals are purple and fused into a two-lipped tube. Similar in appearance to purple deadnettle but upper leaves lack petioles.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Very common throughout region.
- **Notes:** Stems grow primarily upright.

Parsley-piert

- **Description:** About 1- to 3-inches tall and freely branched. Leaves are alternate and as three-lobed with each lobe again three- to four-lobed. May be petiolate or sessile with a cone-shaped toothed portion (stipules) at the base that encircles the stem and surrounds the inconspicuous flowers in axillary clusters.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Maryland through Tennessee into Georgia.

Spurweed or lawn burweed

- **Description:** Low-growing and freely branched. Leaves opposite, sparsely hairy and twice divided into narrow segments or lobes. Flowers are small (to 1/4 inch), broad, and inconspicuous, borne sessile in the forks of branches. Seeds have sharp spines that can cause injury to humans, hence the common name.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Generally found in the Coastal Plain and Piedmont Regions of most southern states, North Carolina south into Florida, and west to Texas.
- **Notes:**
    - Controlled with herbicides such as 2,4-D, MCPA, MCPP, dicamba, clopyralid, triclopyr, and fluroxypyr.
    - Atrazine, simazine and metribuzin are also used in tolerant turfgrass species.
    - Preemergence herbicides not commonly used but some dinitroaniline herbicides have activity.

Winter annual grass weeds

General IPM and/or management issues: Annual grasses pose a problem because of their vigorous growth, competitive nature, and ability to produce copious amounts of seed.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Control Measures recommended and used:

Cultural/mechanical: Maintain a healthy, dense turf.

- ***Avoid:***
  - excessively close mowing;
  - shallow, frequent irrigation;
  - poor soil drainage;
  - improperly timed fertilization;
  - aerifying or dethatching during primary periods of annual bluegrass germination;
  - use of heavy equipment causing compaction; and shade.

Biological: No biological control options are currently available for use.

Chemical:

- Preemergence herbicides applied in the fall before annual bluegrass emerges give effective control.

Pest name (common, scientific): Annual bluegrass (*Poa annua* L.).

Description, distribution, importance and control measures used and recommended for each weed

- **Description:** A small, light green bunch-type to slightly spreading weedy grass. Leaf blade, smooth on both surfaces, with two distinct, clear lines, one on each side of the midrib. Leaf tip keeled or boat-shaped. Ligule membranous. Light green to whitish spikelets that lack cottony hairs, are arranged on branches, one to two per node,in dense to open flower clusters.
- **Reproduction:** Seed.
- **Distribution within Southern region:** Throughout.
- **Notes:**
  - *Poa annua* flourishes under close mowing conditions, and its invasion of highly maintained golf course putting greens severely impairs quality. *Poa annua* is also a major problem in warm-season turfgrasses.
  - Annual bluegrass can be effectively controlled in dormant bermudagrass with glyphosate or with herbicides such as simazine or atrazine (Simazine and atrazine can also be used in other warm-season turf species).
  - Other herbicides used to control this weed are various preemergence herbicides, Prograss, Monument, Certainty, Revolver, TranXit and Kerb.

Algae and Mosses

Pest Name(s) (common, scientific): algae and mosses (multiple spp.)

Distribution, damage and importance:

Algae are unicellular or multicellular threadlike green plants that form a thin dense green scum over the soil surface. This scum forms a tough black crust that when dry which acts as a barrier impeding the entrance of water and nutrients into the soil. Algae are competitive in compacted, waterlogged soils.

Mosses are green plants with leaves arising from all sides of a central axis. Mosses may grow erect or prostrate. They typically form a thick green mat at the soil surface. Conditions favoring the growth of mosses include low fertility, poorly drained soils, high soil acidity, excessively wet soils, soil compaction, excessive thatch or a combination of these factors that add up to thin or weak turf.

Physical or chemical removal of these pests will only be temporary unless growing conditions are improved.

Host(s): All turfgrass.

Chronology: Algae are more common when conditions are warm, sunny and humid conditions, whereas mosses prefer cool, moist shaded locations. Both pests thrive where the ground remains wet for extended periods of time.

Control measures used and recommended:

Cultural/mechanical:

- Reduce shade or plant shade-tolerant grasses
- Prepare a new seedbed and replant if large bare areas exist.
- Avoid excessive watering and improve irrigation scheduling if necessary.
- Improve soil drainage.
- Aerify compacted soils.
- Conduct a soil test to determine proper lime and fertilizer needs. Lime is necessary to reduce soil acidity. Proper fertilization will aid in preventing weed encroachment.
- Increase air movement and light penetration in shaded areas by removing unnecessary undergrowth and pruning tree limbs.
- *Algae:* Punch holes in the alga crust or remove the crust entirely to allow turf recovery in these areas.
- *Moss*: Physical removal of the moss by raking may be needed to allow turf recovery in these areas.

Biological:

- None noted.

Chemical:

- *Algae* may be controlled with copper sulfate at the rate of 2 to 3 ounces per 1,000 square feet or one teaspoon in 8 gallons of water. An application of 5 to 10 pounds of ground limestone per 1,000 square feet prior to reseeding will help to inactivate the copper sulfate that may be toxic to grass seedlings.
- *Moss* may be controlled with copper or ferrous sulfate sprayed at 5 ounces per 1,000 square feet in 4 gallons of water. Applying concentrated amounts (10 ounces per 1,000 square feet) of ferrous ammonium sulfate to the moss spots when the moss is damp offers another means of control. Ferrous ammonium sulfate should not be watered in. An

application of 5 to 10 pounds of ground limestone per 1,000 square feet prior to reseeding will help to inactivate the copper sulfate that may be toxic to grass seedlings.

State/local pesticide restrictions or limitations, export issues, etc.: None noted.

Critical issues: None noted.

Chemicals used:

Phenylpyrroles:	Fludioxonil
Substituted aromatics:	Chlorothalonil
Dithiocarbamates and relatives:	Mancozeb
Inorganics:	copper hydroxide, copper or ferrus sulfate

Overall Needs for Management of Weed, Algal and Moss Pests of Turf

Regulatory:

- More strict enforcement of existing regulations.
    - In particular, application by non-certified applicators.
- Require more continuing education for certified applicators.
- Greater role for regulators in education.
    - Funding for Extension.
        - Revision of educational criteria to encourage annual training (e.g., Georgia).
- Reclassification of sod production into EPA agricultural production as opposed to non-crop land.
    - Permit use of agricultural chemical products in sod production.

Research:

- Perennial grass control in turf.
- Weed control during establishment.
- Methyl bromide alternatives.
- More chemical alternatives for resistance management.
- Environmental implications of herbicide resistant grass (biotech).
- Environmental fate of herbicides.
- Biology and control of mosses and algae.
- Postemergence control of perennial grass weeds such as nimblewill, dallisgrass, vaseygrass, torpedograss and common bermudagrass.
- Selective control of one turfgrass species that is growing as a weed in a different turfgrass species.
- Develop control programs for "newer" turfgrass weeds such as niruri, doveweed and lindernia (*Lindernia crustacea*).
- Biology and ecology of turfgrass weeds.
- Develop effective control programs for Virginia buttonweed, annual bluegrass, sedge and *Kyllinga* ssp.
- Develop weed management strategies for herbicide-tolerant turfgrasses.
- Develop integrated control programs to prevent the development of herbicide-resistant weeds.
- Develop effective cultural and mechanical methods to control turfgrass weeds (i.e. non-chemical).
- Elucidate soil parameters that influence turfgrass weed populations.
- Document shifts in weed species that may occur due to cultural methodology, or changing herbicide use patterns and chemistries.
- Determine invasive nature and prevent turfgrass species encroachment into native plant communities.

Education:

- Biology and control of mosses and algae.

- Develop high-quality electronic and conventional publications for ecology and biology of weeds in turfgrasses.
- Develop high-quality electronic and conventional publications for weed management in turfgrasses.
- There is strong need to develop a comprehensive, college-level text-book on turfgrass pest (weeds, insects, diseases) management.
- Conduct appropriate workshops, field days and conferences for professional turfgrass managers as well as retail professionals.

Herbicides and Algaecides used

Preemergence herbicides

Atrazine (Atrazine 4L, Aatrex 4L, others)

- Use: Preemergence and postemergence control of annual bluegrass and many annual broadleaf weeds.
- Efficacy: Good to excellent.
- Resistance issues: Pigweed, annual bluegrass, common ragweed and common lambsquarters are among the weed species that have been reported resistant to this herbicide family (triazine).
- Soil half-life: 60 d.
- Other notes: Used only in certain warm-season turfgrasses. Widely used in centipedegrass and St. Augustinegrass. Restricted use herbicide. The restrictions on atrazine such as the 200' setback from retention ponds, rate restrictions, PPE coverall requirements for lawn care spot treatments and other issues make atrazine use in the 44% concentrated form difficult.
- REI: Seed or sod farms – 12 hours; other turf sites – none.
- HRAC Mode of Action Classification: C1.
- WSSA Mode of Action Classification: 5.

Benefin (Balan)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds.
- Efficacy: Good.
- Resistance issues: Goosegrass and annual bluegrass resistance has been reported for this herbicide family (dinitroaniline).
- Soil half-life: 40 d.
- Other notes: May be used on all cool- and warm-season turfgrasses with the exception of golf course putting greens. Needs 0.25 to 0.5 inches of rain or irrigation water within 5 to 7 days after application. Labeled for use in cool- and warm-season turfgrasses.
- REI: Seed or sod farms – none; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Bensulide (Bensumec, others)

- Use: Control of annual grasses.
- Efficacy: Excellent for the control of crabgrass.
- Resistance issues: Not classified as to herbicide family.
- Soil half-life: 120 d.
- Other notes: May be used on all cool- and warm-season turfgrasses including putting greens. Needs 0.25 to 0.5 inches of rain or irrigation water within 5- to 7-days after application. Labeled for use in cool- and warm-season turfgrasses.
- REI: Seed or sod farms – none; other turf sites – none.
- HRAC Mode of Action Classification: N.
- WSSA Mode of Action Classification: 8.

Dithiopyr (Dimension)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds.
- Efficacy: Good to excellent. Also provides postemergence control of seedling crabgrass.
- Resistance issues: Goosegrass and annual bluegrass resistance has been reported for this herbicide family (pyridine).
- Soil half-life: 17 d.
- Other notes: May be used on all cool- and warm-season turfgrasses excluding putting greens. Needs 0.25- to 0.5-inches of rain or irrigation water within 5- to 7-days after application. Labeled for use in cool- and warm-season turfgrasses.
- REI: Seed or sod farms – 12 hours; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Isoxaben (Gallery)

- Use: Preemergence control of broadleaf weeds that arise from seed.
- Efficacy: Good preemergence control of broadleaf weeds.
- Resistance issues: None (benzamide).
- Soil half-life: 50 to 120 d.
- Other notes: May be tank-mixed with other preemergence herbicides to improve annual grass control. Needs 0.25- to 0.5-inches of rain or irrigation water within 5- to 7-days after application. Labeled for use in cool- and warm-season turfgrasses.
- REI: Seed or sod farms – 12 hours; other turf sites – none.
- HRAC Mode of Action Classification: L.
- WSSA Mode of Action Classification: 21.

Metolachlor (Pennant Magnum)

- Use: Preemergence control of annual grasses, annual sedges and yellow nutsedge.
- Efficacy: Good preemergence control of annual grasses and yellow nutsedge
- Resistance issues: None (chloroacetamide).
- Soil half-life: 15 to 25 d (bioassay method).
- Other notes: Only preemergence herbicide for annual sedge and yellow nutsedge control. Will not control purple nutsedge. Needs 0.25- to 0.5-inches of rain or irrigation water within 5- to 7-days after application. Labeled for use in warm-season turfgrasses.
- REI: Seed or sod farms – 12 hours; other turf sites – none.
- HRAC Mode of Action Classification: K3.
- WSSA Mode of Action Classification: 15.

Oryzalin (Surflan)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds.
- Efficacy: Good to excellent preemergence control of annual grasses.
- Resistance issues: Goosegrass and annual bluegrass resistance has been reported for this herbicide family (dinitroaniline).
- Soil half-life: Ranges from 20 to 128 d.

- Other notes: Needs 0.25- to 0.5-inches of rain or irrigation water within 21 d after application.
- REI: Seed or sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Oxadiazon (Ronstar)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds
- Efficacy: Very effective for goosegrass control.
- Resistance issues: None (oxadiazole).
- Soil half-life: 60 d.
- Other notes: Needs 0.25 to 0.5 inches of rain or irrigation water within 5- to 7-days after application. May also be applied at the time for sprigging bermudagrass and zoysiagrass. Delay application until 14 days after sprigging seashore paspalum. Labeled for use in cool- and warm-season turfgrasses.
- REI: Seed or sod farms – 12 hours; other turf sites – none.
- HRAC Mode of Action Classification: E.
- WSSA Mode of Action Classification: 14.

Pendimethalin (Pendulum, Pre-M)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds.
- Efficacy: Excellent preemergence control of annual grasses, henbit and common chickweed.
- Resistance issues: Goosegrass and annual bluegrass resistance has been reported for this herbicide family (dinitroaniline).
- Soil half-life: 44 d.
- Other notes: Same family as oryzalin but less phytotoxic to cool-season turfgrasses. Needs 0.25- to 0.5-inch of rainfall or irrigation water to activate.
- REI: Seed and sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Prodiamine (Barricade)

- Use: Preemergence control of annual grasses and certain annual broadleaf weeds.
- Efficacy: Excellent preemergence control of annual grasses, henbit and common chickweed.
- Resistance issues: Goosegrass and annual bluegrass resistance has been reported for this herbicide family (dinitroaniline).
- Soil half-life: 70 d.
- Other notes: Labeled for use in cool- and warm-season turfgrasses. Long soil half-life. Late fall to early winter applications in some geographical areas have shown acceptable levels of crabgrass spp. control the following year.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

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Pronamide (Kerb)

- Use: Primarily used for annual bluegrass control in warm-season turfgrass species.
- Efficacy: Good for control of weedy cool season grasses. Has both preemergence and postemergence activity on annual bluegrass.
- Resistance issues: None (substituted amide).
- Soil half-life: 60 d.
- Other notes: For maximum activity, pronamide should be applied when soil temperature is less than 55 Fº. Subject to surface (lateral) movement on sloped areas. Highly injurious to cool-season turfgrasses. Restricted Use herbicide.
- REI: Seed and sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Siduron (Tupersan)

- Use: Controls crabgrass species and certain other summer annual grasses in cool-season turfgrasses and zoysiagrass.
- Efficacy: Good to excellent control of crabgrass.
- Resistance issues: Weed resistance has been reported for this herbicide family (substituted urea).
- Soil half-life: 90 d.
- Other notes: May also be applied at the time of seeding cool-season turfgrasses, sprigging zoysiagrass, and to suppress bermudagrass encroachment into creeping bentgrass putting greens. Does not control annual bluegrass, goosegrass and fall panicum.
- REI: Seed or sod farms – 4 h.; other turf sites – none.
- HRAC Mode of Action Classification: C2.
- WSSA Mode of Action Classification: 7.

Simazine (Princep)

- Use: Preemergence and postemergence control of annual bluegrass and most winter annual broadleaf weeds.
- Efficacy: Good to excellent.
- Resistance issues: Pigweed, annual bluegrass, common ragweed and common lambsquarters are among the weed species that have been reported resistant to this herbicide family (triazine).
- Soil half-life: 60 d.
- Other notes: Low cost. Used only in certain warm-season turfgrasses.
- REI: Seed and sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: C1.
- WSSA Mode of Action Classification: 5.

Postemergence herbicides

2,4-D (numerous formulations and trade names))

- Use: Controls numerous annual and perennial broadleaf weeds.

- Efficacy: Particularly effective for control for dandelion and plantains.
- Resistance issues: None in turfgrasses (phenoxy).
- Soil half-life: 10 d.
- Other notes: Recommended for use on all turfgrasses, except St. Augustinegrass. Normally sold in prepackaged mixtures with varying amounts of MCPP, dicamba, fluroxypyr, triclopyr, 2,4-DP, MCPA, clopyralid or carfentrazone.
- REI: Seed or sod farms – 48 h.; other turf sites – none.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Bentazon (Basagran T&O)

- Use: Controls yellow nutsedge, annual sedges, dayflower and certain annual broadleaf weeds.
- Efficacy: Good to excellent on labeled weeds.
- Resistance issues: None (benzothiadiazole).
- Soil half-life: 20 d.
- Other notes: May be used on all turfgrass species and sites except putting greens. Two applications, spaced 10- to 14-d. apart are needed for yellow nutsedge.
- REI: Seed or sod farms – 48 h.; other turf sites – none.
- HRAC Mode of Action Classification: C3.
- WSSA Mode of Action Classification: 6.

Bispyribac-Sodium (Velocity)

- Use: Primarily used for the control of emerged annual bluegrass in bermudagrass fairways overSoded with perennial ryegrass.
- Efficacy: Provides good control of annual bluegrass.
- Resistance issues: None (pyrimidunyloxybenzoic).
- Soil half-life: Less than 10 d.
- Other notes: Requires repeat applications to control annual bluegrass. Not recommended for use on putting greens.
- REI: Seed or Sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

Carfentrazone (QuickSilver)

- Use: Controls a wide range of broadleaf weeds.
- Efficacy: Good for broadleaf weed control. Not effective for the control of weedy grasses.
- Resistance issues: None (aryl triazinone).
- Soil half-life: Less than 0.1 d.
- Other notes: Fast acting contact herbicide. May be used alone or in combinations with most other postemergence herbicides. Prepackaged mixtures of carfentrazone with certain postemergence herbicides are now in the market place. May be used on creeping bentgrass putting greens for the control of silvery-thread moss (*Byrum argenteum*) in certain southern states. Does not provide preemergence weed control.
- REI: Seed or sod farms – allow spray to dry; other turf sites – none.

- HRAC Mode of Action Classification: E.
- WSSA Mode of Action Classification: 14.

Chlorsulfuron (Corsair)

- Use: Primarily used to control tall fescue and certain broadleaf weeds, such as violet species, in certain turfgrasses except centipedegrass, ryegrass and St. Augustinegrass.
- Efficacy: Effective.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 40 d.
- Other notes: Due to single site-of-action, chlorsulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of chlorsulfuron-resistant weeds.
- REI: Seed or sod farms – 4 h.; other turf sites – allow sprays to dry.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

Clethodim (Envoy)

- Use: Postemergence control of annual grasses and common bermudagrass.
- Efficacy: Good control of annual grasses and common bermudagrass.
- Resistance issues: Perennial ryegrass, Italian ryegrass and goosegrass have shown resistance to this herbicide family (cyclohexanedione).
- Soil half-life: Approximately 3 d.
- Other notes: Use is restricted to centipedegrass Sod farms in certain southern states..
- REI: Sod farms – 24 h.
- HRAC Mode of Action Classification: A.
- WSSA Mode of Action Classification: 1.

Clopyralid (Lontrel)

- Use: Selective control of broadleaf weeds.
- Efficacy: Effective for the control of most species in the legume and aster plant families.
- Resistance issues: None (pyridinecarboxylic acid).
- Soil half-life: 12 to 70 d.
- Other notes: Not labeled for use on residential properties.
- REI: Seed and sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Dicamba (Vanquish, Banvel)

- Use: Controls numerous annual and perennial broadleaf weeds.
- Efficacy: Provides better control of common chickweed, henbit and white clover than 2,4-D.
- Resistance issues: None (benzoic acid).
- Soil half-life: 14 d.

- Other notes: May be used in all turfgrass species with the exception of putting greens. Normally sold in prepackaged mixtures with varying amounts of 2,4-D, MCPP, fluroxypyr, triclopyr, 2,4-DP, MCPA, clopyralid or carfentrazone.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Diclofop (Illoxan)

- Use: Controls goosegrass.
- Efficacy: Excellent when applied to goosegrass in the early tiller growth stage.
- Resistance issues: Perennial ryegrass, Italian ryegrass and goosegrass have shown resistance to this herbicide family (aryloxyphenoxy propionate).
- Soil half-life: 30 d.
- Other notes: Labeled only for use bermudagrass fairways, tees and putting greens on golf courses. Restricted Use herbicide. Lack of rotation to herbicides with a different mode-of-action has led to the development of Illoxan-resistant goosegrass and Italian ryegrass.
- REI: None.
- HRAC Mode of Action Classification: A.
- WSSA Mode of Action Classification: 1.

Diquat (Reward L&A)

- Use: Control of winter annual broadleaf weeds in dormant bermudagrass.
- Efficacy: Controls several annual broadleaf weeds. Not effective for annual bluegrass control.
- Resistance issues: None (bipyridilium).
- Soil half-life: 1,000 d.
- Other notes: Diquat is almost irreversibly bound to negatively-charged sites on clay micelles and is not biologically available.
- REI: Seed or sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: D.
- WSSA Mode of Action Classification: 22.

Ethofumesate (Prograss)

- Use: Preemergence and early postemergence control/suppression of annual bluegrass in bermudagrass overSoded with perennial ryegrass. Also, can be used alone or tank-mixed with atrazine for bermudagrass control in St. Augustinegrass.
- Efficacy: Good when applied according to label directions.
- Resistance issues: None. Annual bluegrass has been shown in some geographical areas to be resistant to ethofumesate (not classified as to herbicide family).
- Half-life: 5 to 14 wks.
- Other notes: Applied at various time intervals after perennial ryegrass emergence.
- REI: Seed or sod farms – 12 h.; other turfgrass sites – none.
- HRAC Mode of Action Classification: N.
- WSSA Mode of Action Classification: 16.

Fenarimol (Rubigan)

- Use: Preemergence control/suppression of annual bluegrass on bermudagrass putting greens. Primarily used as fungicide for the control of various turfgrass diseases.
- Efficacy: Good when applied in a series of two to three applications before oversoding.
- Resistance issues: None.
- Half-life: 12 h. (foliar).
- Other notes: No significant postemergence control of annual bluegrass. The last application should be made two and four weeks before oversoding with perennial ryegrass or *Poa trivialis*, respectively.
- REI: Seed or sod farms – 12 h.; other turfgrass sites – none.
- HRAC Mode of Action Classification: ?
- WSSA Mode of Action Classification: ?

Fenoxaprop (Acclaim Extra)

- Use: Controls various annual and perennial grass weeds in cool-season turfgrasses and zoysiagrass.
- Efficacy: Good to excellent when applied at the correct stage of weed growth.
- Resistance issues: Perennial ryegrass, Italian ryegrass and goosegrass have shown resistance to this herbicide family (aryloxyphenoxy propionate).
- Soil half-life: 9 d.
- Other notes: Grass needs to be actively growing and not under stress. Can be used in combination with triclopyr ester for common bermudagrass control in tall fescue and zoysiagrass. Timing is critical, more effective on smaller grasses.
- REI: Seed or sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: A.
- WSSA Mode of Action Classification: 1.

Fluazifop-P-butyl (Fusilade II)

- Use: Controls most annual grasses.
- Efficacy: Good to excellent.
- Resistance issues: Perennial ryegrass, Italian ryegrass and goosegrass have shown resistance to this herbicide family (aryloxyphenoxy propionate).
- Residual: 15 d.
- Other notes: Grass needs to be actively growing and not under stress. Can be used in combination with triclopyr ester for common bermudagrass control in zoysiagrass. Timing critical, more effective on smaller grasses.
- REI: Seed and sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: A.
- WSSA Mode of Action Classification: 1.

Fluroxypyr (Spotlight)

- Use: Selective control of broadleaf weeds.
- Efficacy: Good to excellent on weeds shown on product label.
- Resistance issues: None (pyridinecarboxylic acid).
- Soil half-life: 11 to 38 d.

- Other notes: Primarily used in cool-season turfgrasses and zoysiagrass.
- REI: Seed and sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Foramsulfuron (Revolver)

- Use: Controls cool-season grasses, certain annual broadleaf weeds and goosegrass.
- Efficacy: Effective on labeled weeds.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 5 d.
- Other notes: Also used to remove perennial ryegrass from oversoded bermudagrass. Due to single site-of-action, foramsulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of foramsulfuron-resistant weeds.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.
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Glufosinate (Finale)

- Use: Non-selective control of emerged weeds.
- Efficacy: Effectively control most annual weeds. Due to limited translocation, control of most perennial species is not effective.
- Resistance issues: None (phosphorylated amino acid).
- Soil half-life: 7 d.
- Other notes: May also be used in dormant bermudagrass. Advances in biotechnology have shown that glufosinate-tolerant turfgrasses can be developed.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: H.
- WSSA Mode of Action Classification: 10.

Glyphosate (Roundup and others)

- Use: Non-selective control of emerged weeds.
- Efficacy: Controls most weeds.
- Resistance issues: Palmer amaranth and horseweed have been documented in some states. (not classified as to family).
- Soil half-life: 47 d.
- Other notes: Extensively translocated. Non-volatile. Glyphosate-tolerant turfgrasses are currently in development.
- REI: Seed and sod farms – 4 h.; other turf sites – none.
- HRAC Mode of Action Classification: G.
- WSSA Mode of Action Classification: 9.

Halosulfuron (Sedgehammer, Manage)

- Use: Controls sedge (*Cyperus* spp.) and kyllinga (*Kyllinga* spp.) species.
- Efficacy: Highly effective. Turfgrasses have excellent tolerance to halosulfuron.

- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 4 to 12 d.
- Other notes: May be used on all cool- and warm-season turfgrasses with the exception of golf course putting greens. Apply with a nonionic surfactant. Needs to be re-applied if regrowth is noted (usually about 6 to 10 weeks. Due to single site-of-action, halosulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of halosulfuron-resistant weeds.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

Imazaquin (Image)

- Use: Controls sedge (*Cyperus* spp.) and kyllinga (*Kyllinga* spp.) species, sandbur, wild garlic, and certain broadleaf weeds.
- Efficacy: Effective.
- Resistance issues: Certain broadleaf weed species have shown resistance to this herbicide family (imidazolinone).
- Soil half-life: Around 1 month.
- Other notes: Used only on bermudagrass, centipedegrass, St. Augustinegrass and zoysiagrass. Tank-mixtures with MSMA often show better sedge control than imazaquin used alone.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

MCPP (Mecomec 4)

- Use: Controls annual and perennial broadleaf weeds.
- Efficacy: Provides better control of common chickweed, white clover and prostrate spurge than 2,4-D.
- Resistance issues: None in turfgrasses (phenoxy).
- Soil half-life: 21 d.
- Other notes: Recommended for use on all turfgrasses except centipedegrass and St. Augustinegrass. Commonly sold in prepackaged mixtures with varying amounts of 2,4-D, dicamba, fluroxypyr, triclopyr, 2,4-DP, MCPA, clopyralid or carfentrazone. May also be used on creeping bentgrass and bermudagrass putting greens.
- REI: Seed or sod farms – 48 h.; other turf sites – none.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Metribuzin (Sencor)

- Use: Controls annual broadleaf weeds, annual bluegrass and goosegrass in bermudagrass.
- Efficacy: Effective on labeled weeds.

- Resistance issues: Pigweed, annual bluegrass, common ragweed and common lambsquarters are among the weed species that have been reported resistant to this herbicide family (triazine).
- Soil half-life: 14 to 28 d.
- Other notes: Use only on bermudagrass. Not labeled for use on seed or sod farms. Tank-mixtures with MSMA are commonly used to increase control of weedy grasses.
- REI: Seed or sod farms – not applicable; other turf sites – allow sprays to dry.
- HRAC Mode of Action Classification: C1.
- WSSA Mode of Action Classification: 5.

Metsulfuron (Manor, Blade)

- Use: Primarily used to control certain broadleaf weeds, 'Pensacola' bahiagrass and wild garlic in warm-season turfgrasses (except bahiagrass).
- Efficacy: Highly effective at very low application rates.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 1 to 6 wks.
- Other notes: Also used as a spring transition aid in oversoded bermudagrass. Due to single site-of-action, metsulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of metsulfuron-resistant weeds.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

MSMA, DSMA, CMA (numerous formulations and trade names)

- Use: Controls crabgrass species, dallisgrass, bahiagrass and certain annual brodaleaf weeds. Also, controls annual sedge and kyllinga species.
- Efficacy: Effective, but most weeds require two to three applications.
- Resistance issues: None in turfgrasses (organic arsenical).
- Soil half-life: 180 d.
- Other notes: Use only in tall fescue, zoysiagrass, bermudagrass and Kentucky bluegrass. Turfgrass tolerance decreases at air temperatures above 85^0 F. Do not use on centipedegrass and St. Augustinegrass.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: Z.
- WSSA Mode of Action Classification: 17.

Pronamide (Kerb)

- Use: Preemergence and postemergence control of cool season grasses.
- Efficacy: Effective when applied during cool months of the year.
- Resistance issues: None (substituted amide).
- Soil half-life: 60 d.
- Other notes: Other notes: For maximum activity, pronamide should be applied when soil temperature is less than 55 degrees F. Subject to surface (lateral) movement on sloped areas. Highly injurious to cool-season turfgrasses. Restricted Use herbicide.

- REI: Seed and sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: K1.
- WSSA Mode of Action Classification: 3.

Quinclorac (Drive)

- Use: Controls certain summer annual grasses, torpedograss and broadleaf weeds.
- Efficacy: Effectively controls labeled weeds.
- Resistance issues: None in turfgrasses (unclassified herbicide family).
- Soil half-life: > 180 d.
- Other notes: Recommended for use in cool-season turfgrasses, bermudagrass and zoysiagrass. May also be applied at the time of Soding or sprigging tolerant turfgrasses. Injurious to centipedegrass and St. Augustinegrass.
- REI: Seed or sod farms – 12 h.; other turf sites – none.
- HRAC Mode of Action Classification: O, L.
- WSSA Mode of Action Classification: 4, 27.

Rimsulfuron (TranXit)

- Use: Controls annual bluegrass, cool-season grasses and certain annual broadleaf weeds. Also applied 10 to 14 d. in advance of oversoding bermudagrass with perennial ryegrass and/or *Poa trivialis* for the control of annual bluegrass.
- Efficacy: Effective on labeled weeds. Also recommended for use in centipedegrass and zoysiagrass.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 2 to 5 d.
- Other notes: Also used to remove perennial ryegrass from oversoded bermudagrass. Due to single site-of-action, rimsulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of rimsulfuron-resistant weeds.
- REI: Seed or sod farms – 4 h.; other turf sites – allow sprays to dry.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

Sethoxydim (Vantage)

- Use: Controls annual grasses, bahiagrass and common bermudagrass in fine fescue and centipedegrass.
- Efficacy: Good to excellent grass control.
- Resistance issues: Perennial ryegrass, Italian ryegrass and goosegrass have shown resistance to this herbicide family (cyclohexanedione).
- Soil half-life: 5 d.
- Other notes: Most effective on younger, actively growing grasses (not under moisture stress).
- REI: Seed or sod farms – 12 h.; other turf sites – allow sprays to dry.
- HRAC Mode of Action Classification: A.
- WSSA Mode of Action Classification: 1.

Sulfosulfuron – Certainty (Monsanto)

- Use: Selective herbicide for control of annual and perennial sedges, cool-season grasses grass, and certain broadleaf weeds.
- Efficacy: Has excellent activity on sedge and kyllinga species.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 14 to 75 d.
- Other notes: May be applied to common and hybrid bermudagrass, zoysiagrass, centipedegrass, and St. Augustinegrass. Due to single site-of-action, sulfosulfuron must be rotated with herbicides that have a different mode-of-action to prevent the development of sulfosulfuron-resistant weeds.
- REI: Seed and sod farms – 24 h.; other turf sites – none.
- HRAC Mode of Action Classification: B.
- WSSA Mode of Action Classification: 2.

Triclopyr (Turflon Ester)

- Use: Controls annual and perennial broadleaf weeds.
- Efficacy: Effective. Repeat applications will control wild violet.
- Resistance issues: None (pyridinecarboxylic acid).
- Soil half-life: 10 to 46 d.
- Other notes: Cool-season turfgrasses and zoysiagrass have good to excellent tolerance to triclopyr. May be tank-mixed with fenoxaprop or fluazifop-P-butyl for control of bermudagrass in tolerant turfgrass species.
- REI: Seed or sod farms – 12 h.; other turf sites – allow sprays to dry.
- HRAC Mode of Action Classification: O.
- WSSA Mode of Action Classification: 4.

Trifloxysulfuron (Monument)

- Use: Controls annual bluegrass, cool-season grasses, sedges, kyllinga species and certain annual broadleaf weeds in bermudagrass and zoysiagrass.
- Efficacy: Effective on labeled weeds.
- Resistance issues: Numerous broadleaf weeds and Italian ryegrass has shown resistance to this herbicide family (sulfonylurea).
- Soil half-life: 5 to 15 d.
- Other notes: Also used to remove perennial ryegrass from overSoded bermudagrass. Due to single site-of-action, trifloxysulfuron-Sodium must be rotated with herbicides that have a different mode-of-action to prevent the development of trifloxysulfuron-Sodium-resistant weeds.
- REI: Seed or sod farms – 12 h.; other turf sites – none.

HRAC Mode of Action Classification: B.
WSSA Mode of Action Classification: 2.

Biotechnology use in turf pest management

Fungal diseases cause a significant amount of damage to turfgrasses in the Southern Regions. Many currently used fungicides are potential carcinogens and will likely be phased out in the future. One alternative to fungicide use is to introduce fungal disease resistance genes into turfgrass either through conventional breeding or via a biotechnological approach. The resulting disease resistant cultivars could significantly reduce the use of fungicides.

An obstacle to conventional breeding is that the existing germplasm pool of a turfgrass species may not have an effective resistance gene, or resistance is overcome by new races of a fungal pathogen. In such cases, a biotechnological approach could be used to introduce fungal resistance genes from other plant species and potentially from non-plant species. Genes for resistance to fall armyworm and other insect and mite pests are being identified so that they can be isolated and transformed into other cultivars and species of turf which do not have the resistance in the available gene pools. The genes for abiotic stress resistance should also be identified to enable the transformation of improved cultivars with drought, cold and salt resistance.

Other pest problems, such as nematode damage to bermudagrass and zoysiagrass, also do not have resistance genes from their germplasm pool, and would require the introduction of resistance genes from other species. Drought tolerance as well as the development of herbicide resistant turf varieties are also targets of biotechnology efforts.

Four research programs in Southern Regions are seriously involved in turfgrass transformation efforts for trait improvement.

(1) Dr. Wayne Hanna at the University of Georgia, Tifton, is developing herbicide (glufosinate) resistant "TifEagle" bermudagrass by introducing the herbicide resistant *bar* gene.
(2) Dr. Fredy Altpeter at the University of Florida, Gainesville, has the ability to transform perennial ryegrass using both particle bombardment and *Agrobacterium* approaches, and is working on isolating drought tolerance genes.
(3) Dr. Rongda Qu at North Carolina State University is working on tall fescue and bermudagrass transformation for fungal disease resistance, drought tolerance, and nematode resistance.
(4) Dr. M.C. Engelke and cooperators at the Texas A&M University System are in the process of identifying and isolating the genes for fall armyworm resistance from *Zoysia* and *Poa* and the genes for salt tolerance from *Zoysia* as well.

Top Plant Breeding and Biotechnology Needs

- U.S. and foreign expeditions to collect wider genepool to expand germplasm base available to breeding programs.
- Development of new cultivars to fit nitch uses i.e. shaded lawns and sports fields, use of gray or salty water for irrigation, Indoor sports arenas.
- Better understanding of the turf ecology relative to new varieties. In particular the weedy problems that have been created as a result of bermudagrass and *Poa annua.*
- Understand the interaction of turf species interface (e.g. golf green/fairway).
- Risk assessment of new varieties that can be used in new situations (e.g., shade, salt tolerance).
- Impacts of biotic and abiotic factors (e.g., salt tolerance, shade tolerance) as they affect competitive advantage of new species. They can become weeds.
- Molecular understanding of turf species.
- Genetic ID of turf species.
- Evaluating germplasm considering all disciplines (better integration.
- Enhance biotech efforts of turf improvement.
- Develop protocol for risk assessment on gene flow.

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Appendix A.

Efficacy Ratings for *Insecticides, Acaricides and Nematicides*

Rating scale: E = excellent; G = good; F = fair; P = poor; ? = more research needed; N = not used; Y = technique is used
* = used but not necessarily a stand alone management tool (M=mound drench)

Arthropod Pests: Pest management tools:	Tawny/shortwinged mole cricket	Southern mole cricket	Japanese beetles	Masked chafers	Green June beetles	May/June Beetle	Oriental beetle	Sugarcane Beetle	Hunting / Bluegrass billbug	Armyworm	Black cutworm	Sod webworm	Southern chinch bug	Two-lined spittlebug	Red imported fire ant	Atenius/ Aphodius	Ground pearls	Eriophyid Mites
Registered materials:																		
Hydramethylnon (Amdro)	N	N	N												E		?	?
Fenoxycarb (Award)	N	N	N												E		?	?
Abamectin (Ascend)	N	N	N												E		?	?
Spinosad (Conserve, GF-120 Naturalyte Justice)	N	N	N							G	G	E			G		?	?
Pyriproxyfen (Distance)	N	N	N												G-E		?	?
Chlorpyrifos (Dursban)	N	N	P	P	G	P	P	?	E	G	E	E			M* N	P		?
Extinguish	N	N													E			?
Halofenozide (Mach 2)	N	N	E	E	E	E	G	?	E	G	G	?			N	E		?
Acephate (Orthene)	F-G	F-G							?	G	G	?			G*			?
Acephate (Pinpoint)															?			
Carbaryl	Bait G	G	F	F	E	F	F		N	G	G	G	G-E		F*	F	?	H

Arthropod Pests: Pest management tools:	Tawny/shortwinged mole cricket	Southern mole cricket	Japanese beetles	Masked chafers	Green June beetles	May/June Beetle	Oriental beetle	Sugarcane Beetle	Hunting / Bluegrass billbug	Armyworm	Black cutworm	Sod webworm	Southern chinch bug	Two-lined spittlebug	Red imported fire ant	Atenius/ Aphodius	Ground pearls	Eriophyid Mites
(Sevin)																		
Bifenthrin (Talstar)	G-E	G							E	E	E	E	E		G		?	
Lambda cyhalothrin (Scimitar)	F-G	F-G							E	E	E	E	F-G		G*		?	
Cyfluthrin									E	E	E	E	F-G		G*		?	
Permethrin	F-G	F-G							E	E	E	E	E-G		G*		?	
Cypermethrin		F-G							E	E	E	E	G		G*		?	
Trichlorfon (Dylox)		G-E	G-E	G-E	G-E	G-E	G-E		E	G	G	G	E		N	G-E	?	
Imidacloprid	G	G	E	E	E	E	E		E						N	E	?	
Deltamethrin (Suspend)	F-G	F-G											F-G		G			
Fipronil (Chipco Choice, Topchoice, Ceasefire, BASF)	E	E													E			
Azadirachtin										G	G	G						
Bacillus thuringiensis (Dipel, Thuricide, Javelin)										G	G	G						
Ethoprop (Mocap)	G	G										G			N			
Indoxacarb (Avaunt)	F-G	F-G								? G	?	?						
chemical name-(Arena)	F-G	F-G								?	?	?						
Dinotefuran (Safari)										?	?	?					?	
Cultural/Non-																		

Arthropod Pests: Pest management tools:	Tawny/shortwinged mole cricket	Southern mole cricket	Japanese beetles	Masked chafers	Green June beetles	May/June Beetle	Oriental beetle	Sugarcane Beetle	Hunting / Bluegrass billbug	Armyworm	Black cutworm	Sod webworm	Southern chinch bug	Two-lined spittlebug	Red imported fire ant	Atenius/ Aphodius	Ground pearls	Eriophyid Mites
chemical																		
Resistant varieties																		
Sanitation																		Y
Sticky traps																		
Use of certified pest-free plants	Y	Y	Y				Y								Y			Y
Weed control																		
Fertility management													?					Y
Irrigation management																		
Re-tilling fields																		
Encouraging natural enemies	Y	Y																
Reducing nitrogen levels																		
Proper harvest times																		
Spot spraying	Y	Y											Y	Y	Y			
Mowing height				Y	Y	Y	Y							Y			Y	
Biological controls:																		
Aphid midges																		
Bacillus popillae (Milky spore disease)		F																
Beneficial mites																		
Big-eyed bugs																		
Beneficial nematodes	F	F																
Green lacewings																		

Arthropod Pests: Pest management tools:	Tawny/shortwinged mole cricket	Southern mole cricket	Japanese beetles	Masked chafers	Green June beetles	May/June Beetle	Oriental beetle	Sugarcane Beetle	Hunting / Bluegrass billbug	Armyworm	Black cutworm	Sod webworm	Southern chinch bug	Two-lined spittlebug	Red imported fire ant	Atenius/ Aphodius	Ground pearls	Eriophyid Mites
Ladybird beetles																		
Parasites															Y			
Spiders															Y			

Toxicity of insecticides to beneficial insects

Toxicity scale: S = slightly toxic; M = moderately toxic; H = highly toxic; O = nontoxic; ? = no data available

Beneficial insects/mites: Pest management tools:	Beneficial mites	Big-eyed bugs	Beneficial nematodes	Green lacewings	Ladybird beetles	Parasites	Spiders	Bees
Registered materials:								
Hydramethylnon (Amdro)								
Fenoxycarb (Award)								
Abamectin (Ascend)	H				M	M		H
Spinosad (Conserve, GF-120 Naturalyte)								H
Pyriproxyfen (Distance)								
Chlorpyrifos (Dursban)	H	H		H	H	H	H	H
Extinguish								
Halofenozide (Mach 2)								
Acephate (Orthene)								
Acephate (Pinpoint)								
Carbaryl (Sevin)	H					H		H
Bifenthrin (Talstar)	H	H	S	H	H	H	H	H
Bendiocarb (Turcam)								

Appendix B.

Efficacy Ratings for Fungicides

Rating scale: E = excellent; G = good; F = fair; P = poor; ? = more research needed

	Azoxystrobin	Boscolid	Chloroneb	Chlorothalonil	Etridiazole	Fenarimol	Fludioxanil	Flutolanil	Fosetyl Al	Iprodione	Mancozeb	Junction	Metalaxyl/	Myclobutanil	PCNB	Phosphanates	Polyoxin B	Propamocarb	Propiconazole	Pyraclostrobin	Thiophante-	Triadimefon	Trifloxystrobin	Vinclozolin
Pest																								
Algae				G-E							G-E	E												
Anthracnose	G-E			F-G		F-G	F		G	P	F, ?			F-G			F-G		F-G	G	F-G	F	F-G, ?	
Bentgrass deadspot		F					F																?	
Bipolaris (Helminthosporium) leaf spot	G-E, ?			G-E			?			E	G-E			P-F, ?					P-F	G,?	P, ?	P	F, ?	G-E
Bipolaris melting out	G-E									F						?	G			G,?	P		?	
Brown Patch (cool season)	E			G-E		F	G	G-E		G	G-E			F	F		E		F	E	G-G	F	G-E	F
Cercospora leafspot of St. Augustine																								
Copper spot	?			?		?								?					?					
Curvularia fading out	G,?			?						G	G			?					P		G,?	P		
Deadspot		F					F																	
Dollar spot	P	E		G		G				G	P-F			G-E					E	F	E	E	P	E
Fairy ring	G					F-G		G				?								?				
Fusarium patch (Microdochium patch)	F			F		F	E			G	F			F	G-E		G		F-G		G	F	G	F
Gray leaf spot	E			F-G							F			G, ?			?		F	G	E	P-F	F-E, ?	
Large Patch (warm season Brown patch)	E			E		F		G-E		F-G	G-E			F-G			G, ?		F	E, ?	G	P-F	G-E	
Powdery mildew														E					E					
Pythium crown rot																								
Pythium Blight	G-G		F-G		P-G				F-E		F		G			F		G-E		F				

	Azoxystrobin	Boscolid	Chloroneb	Chlorothalonil	Etridiazole	Fenarimol	Fludioxanil	Flutolanil	Fosetyl Al	Iprodione	Mancozeb	Junction	Metalaxyl/	Myclobutanil	PCNB	Phosphanates	Polyoxin B	Propamocarb	Propiconazole	Pyraclostrobin	Thiophante-	Triadimefon	Trifloxystrobin	Vinclozolin
Pest																								
Pythium root rot	?																							
Rapid Blight	F								G													F		
Red thread	E			G		F	F	E						F			?		F	E	E		F	
Rhizoctonia leaf and sheath spot																								
Rusts	E		?	G		G		E		G	G			G, ?					G-E	?	F-E, ?	G-E	F-G, ?	
Slime mold																								
Smut														?					?		?			
Spring dead spot	P-F					P-G								F					P-F		F, ?		?	
Summer patch	E						F							G					G	G	F		G	
Take-All patch bentgrass	E								F										G		F	F		
Take-All St. Aug. bermudagrass	G																		F-G	G	F	F		
Yellow patch	E,?			F		F	F	G	F						G							F		

Appendix C.

Key to response symbols: E = Excellent control (90 to 100%), G = Good control (80 to 89%), F = fair control (70 to 79%), P = Poor control (< 70%). A blank space indicates weed response is not known.

Efficacy Ratings for *Herbicides*: Preemergence

	atrazine	benefin	bensulide	dithiopyr	ethofumesate	fenarimol	isoxaben	metolachlor	napromide	oryzalin	oxadiazon	pendimethalin	prodiamine	pronamide	rimsulfuron	siduron	simazine
PERENNIAL WEEDS																	
bahiagrass	F	P	P	P	P	P	P			P	P	P	P	P			P
bermudagrass	P	P	P	P	P	P	P			P	P	P	P	P			P
dallisgrass	P	P	P	P	P	P	P			P	P	P	P	P			P
nutsedge, purple	P	P	P	P	P	P	P	P		P	P	P	P	P			P
nutsedge, yellow	P	P	P	P	P	P	P	G		P	P	P	P	P			P
perennial kyllinga species								P			P						
tall fescue	F	P	P	P	P	P	P			P	P	P	P	G			F
wild garlic/onion	P	P	P	P	P	P	P			P	P	P	P	P			P
ANNUAL GRASSES																	
annual bluegrass	E	G-E	F	G-E	G-E	G-E	P-F	G	G-E	G-E	G-E	G-E	G-E	G-E	G		E
annual kyllinga species								F-G			F						
annual sedge								G			G						
crabgrass	F	G-E	G-E	G-E		P	P-F	F-G	G-E	E	G-E	E	E	P-F	P	F	P-F
crowfootgrass		G	G			P				G	G	G					
goosegrass	P	F	P-F	F-E		P	P	P-F	G-E	F-G	E	F-E	G-E	P	P		P
sandbur		F	G			P	P			G	F	G					
BROADLEAF WEEDS																	
chamberbitter (niruri)	G					P	G-E										
common chickweed	E	G	P	G		P	E	F	E	G	P	G-E	G	E	P		E
corn speedwell	E	P, E	P	G		P	G-		E	P	G	G-E	F-G	E	P		G-E

	atrazine	benefin	bensulide	dithiopyr	ethofumesate	fenarimol	isoxaben	metolachlor	napromide	oryzalin	oxadiazon	pendimethalin	prodiamine	pronamide	rimsulfuron	siduron	simazine
							E										
cudweed	E	P				P	F			P	P	P		P			
dandelion	F	P	P	P		P	P			P	P	P	P	P			P
dichondra	F	P	P	P		P	P			P	P	P	P	P			P
docks	G	P	P	P		P	P			P	P	P	P	P			P
doveweed	G	P	P		P	P				P	P	P		P			G
Florida betony	E	P	P			P				P	P	P		P			P
ground ivy		P	P	P		P	P			P	P	P	P	P			P
henbit	E	G	P	G		P	G-E		P	G	P	G	G	P-G	P		E
hop clovers	E	P	P			P					G			P			E
knotweed	E		G			P	G			F	G						G
lespedeza	E					P											E
mallow, bristly		P	P	P		P	P			P	P	P	P	P			P
mock strawberry		P	P	P		P	P			P	P	P	P	P			P
mouseear chickweed		E	P			P	G			P	P	G		G			
mugwort		P	P	P		P	P			P	P	P	P	P			P
mustards	E		G			P					E						
parsley piert	E	P	E			P	E				G	P		P			G
pennywort	E	P	P			P				P	P	P		P			P
plantains	G	P	P	P		P				P	P	P	P	P			P
spurges	G-E	P	P	G		P	G-E	F	P	F-G	P-G	F-G	G	P	P		F-G
spurweed (burweed)	G-E	P	P	P		P	G-E		E	F	P	P-G	P-G	P	P		G-E
star-of-Bethlehem				P			P						P	P			P
VA buttonweed		P	P	P		P	P			P	P	P	P	P			P
violets		P	P	P		P	P			P	P	P	P	P			P
white clover	E	P	P	P		P	P			P	P	P	P	P			G
woodsorrel	F-E	P	P	G		P	G	P	G	F-G	G	F-G	G	P	P		P-F

Appendix C (cont.)

Key to response symbols: E = Excellent control (90 to 100%), G = Good control (80 to 89%), F = fair control (70 to 79%), P = Poor control (< 70%). A blank space indicates weed response is not known.

Efficacy Ratings for *Herbicides*: Postemergence

	atrazine	bentazon	bromoxynil	carfentrazone	clopyralid	2,4-D	2,4-D + 2,4-DP	2,4-D + dicamba	2,4-D + triclopyr	dicamba	diclofop	fenoxaprop	fluroxypyr	foramsulfuron	glyphosate	halosulfuron	imazapic	imazaquin
PERENNIAL GRASS/GRASS-LIKE WEEDS																		
bahiagrass	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G			P
bermudagrass	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E			P
dallisgrass	P	P	P	P	P	P	P	P	P	P	P	P	P	F1	E			P
nutsedge, purple	P	P	P	P	P	F	P	P	P	P	P	P	P	P	G	G-E	G	G
perennial kyllinga species		F-G														F-G		G
nutsedge, yellow	P	G	P	P	P	F	P	P	P	P	P	P	P	P	E	G-E	G	F-G
tall fescue	F	P	P	P	P	P	P	P	P	P	P	P	P	G-E	E			P-F
wild garlic/onion	P	P	P	P	P	G	G	G	F	F	P	P			G			E
ANNUAL GRASSES																		
annual bluegrass	E	P	P	P	P	P	P	P	P	P	P	P	P	E	E			P-F
annual kyllinga species		F-G														G		G
annual sedge		G														G	G	G
crabgrass	F	P	P	P	P	P	P	P	P	P	P	G-E	P	P	E			P
crowfootgrass	P	P	P	P	P	P	P	P	P	P		G-E	P	P	E			P
goosegrass	P	P	P	P	P	P	P	P	P	P	E	G	P	G-E	E			P
sandbur	P	P	P	P	P	P	P	P	P	P		G-E	P	P	E			F
BROADLEAF WEEDS																		
chamberbitter (niruri)	G	P			P	P					P	P			E			P

	atrazine	bentazon	bromoxynil	carfentrazone	clopyralid	2,4-D	2,4-D + 2,4-DP	2,4-D + dicamba	2,4-D + triclopyr	dicamba	diclofop	fenoxaprop	fluroxypyr	foramsulfuron	glyphosate	halosulfuron	imazapic	imazaquin
common chickweed	E	G	P	G	P	P	G	G	E	E	P	P	G		E			E
corn speedwell	E	P	G	G		F	F	F	G	F	P	P			E			P
cudweed	G		G		E	G-E	G-E	E	G-E	E	P	P			G			F
dandelion	F	P	P	G	F	E	G	G	G	E	P	P	F-G		E			
dichondra	F	P	P			G	G	G		G	P	P			E			
docks	G	P			G	F	F	G	F-G	E	P	P			E			
doveweed	G-E	P	P		P	P	F	F	F	P	P	P			G			
Florida betony	F-G	P	P		P	F	G	G	G	G	P	P			E			
ground ivy		P	P	G		P-F	F	F	G	G	P	P	G		G			
henbit	E	P	G	G		P	G	G	E	E	P	P	F-G	E	E			G
hop clovers	E		F		E	F	E	G	E	E	P	P			E			
knotweed	E		F			P	F	G	F	E	P	P	G		E			
lespedeza	E				P	P-F	G	G		E	P	P			E			
mallow, bristly		P				F	F-G	F-G	G	E	P	P						
mock strawberry		P				P	P	G		G	P	P						
mouseear chickweed	G	P			P	P-F	G	G	G	E	P	P	G		E			G
mugwort		P				F	F	F		G	P	P			G			
mustards	E	G	G		P	E	G	G		E	P	P			E			
parsley piert	E	G	G		P	P	P		E	E	P	P			E			G
pennywort	E	P	P			G	G	G		E	P	P			E			
plantains	F	P	P			E	G	G	G	F	P	P	F-G		E			
spurges	E	P	F	E		F	G	G	G	G	P	P			E			
spurweed (burweed)	E	E	G		E	G	E	G	E	E	P	P			E			E

	atrazine	bentazon	bromoxynil	carfentrazone	clopyralid	2,4-D	2,4-D + 2,4-DP	2,4-D + dicamba	2,4-D + triclopyr	dicamba	diclofop	fenoxaprop	fluroxypyr	foramsulfuron	glyphosate	halosulfuron	imazapic	imazaquin
star-of-Bethlehem	P	P	G		P	P	P	P	P	P	P	P			F			P
Virginia buttonweed		P	P			P	F	F	F	F	P	P	F		G			
violets		P				P	F	F	F	F	P	P						
white clover	E	P			E	F	G	G	G	E	P	P	E		F			F
woodsorrel	G	P	F			P	P-F	F	F	G	P	P	G		E			

	MCPP	MSMA DSMA CMA	metribuzin	metsulfuron	pronamide	sethoxydim	simazine	sulfosulfuron	triclopyr + clopyralid	trifloxysulfuron-sodium	trifloxysulfuron
PERENNIAL GRASS/GRASS-LIKE WEEDS											
bahiagrass	P	F	P	E	P	F	P		P	F	
bermudagrass	P	P	P	P	P	F	P		P	P	
dallisgrass	P	G	P	P	P	P	P		P	P-F	
nutsedge, purple	P	P-F	P	P	P	P	P	E	P	E	G
perennial kyllinga species		G						E			G
nutsedge, yellow	P	F	P	P	P	P	P		P	E	G
tall fescue	P	P	F	P	E	E	F		P	G-E	
wild garlic/onion	P	P	P	E	P	P	P				
ANNUAL GRASSES											
annual bluegrass	P	P	E	P	E	P	E		P	E	
annual kyllinga species		G									G

	MCPP	MSMA DSMA CMA	metribuzin	metsulfuron	pronamide	sethoxydim	simazine	sulfosulfuron	triclopyr + clopyralid	trifloxysulfuron-sodium	trifloxysulfuron
annual sedge		G									G
crabgrass	P	E	F	P	P	E	P		P	P	
crowfootgrass	P	E	G	P	P	F-G	P		P	P	
goosegrass	P	F	G	P	P	G	P		P	P	
sandbur	P	G	G	P	P	G	P		P	P	
BROADLEAF WEEDS											
chamberbitter (niruri)		P-F				P					
common chickweed	G	P	G	E	G	P	E		E		
corn speedwell	P	P	E	E	G	P	E		P		
cudweed		F-G		E		P			G-E		
dandelion	E	P		E	P	P	P		E	E	
dichondra	F	P			P	P	P		E	E	
docks	P	P		E	P	P	P		E		
doveweed			F	P	P	P	F		P		
Florida betony	G	P			P	P	P		G		
ground ivy	F	P			P	P	P		G-E		
henbit	G	P	G	G	P	P	E		E	E	
hop clovers	E	P	G	P-F		P	E		E	G	
knotweed	F	P	G	E		P					
lespedeza	G	P	E	E		P			E		
mallow, bristly		P		G	P	P	P			P	
mock strawberry		P			P	P	P				
mouseear chickweed	G	P	E	E	P	P	P		E		
mugwort	P	P			P	P	P				
mustards	F	P	F	F	P	P	G				
parsley piert	F	P	E		P	P	E				
pennywort	E	P		G	P	P	P		E		

	MCPP	MSMA DSMA CMA	metribuzin	metsulfuron	pronamide	sethoxydim	simazine	sulfosulfuron	triclopyr + clopyralid	trifloxysulfuron-sodium	trifloxysulfuron
plantains	F	P		G	P	P	P		E	P	
spurges	F	P	E	E		P			F-G	E	
spurweed (burweed)	F	P	G	E	P	P	E		E		
star-of-Bethlehem	P	P	P	P	P	P	P		P		
Virginia buttonweed	P	P		F	P	P	P		F	F-G	
violets	P	P			P	P	P		F-G		
white clover	E	P	F	E	P	P	P		E	G	
woodsorrel	F	G		G	P	P	P		F-G	E	

Appendix D.

Turfgrass Tolerance to Herbicides

TURFGRASS TOLERANCE TO PREEMERGENCE HERBICIDES							
	Bahiagrass	Bermudagrass	Centipedegrass	Kentucky Bluegrass	St. Augustinegrass	Tall Fescue	Zoysiagrass
PREEMERGENCE							
atrazine	NR	D	T	NR	T	NR	I-T
benefin	T	T	T	T	T	T	T
benefin + oryzalin	T	T	T	NR	T	T	T
benefin + trifluralin	T	T	T	T	T	T	T
bensulide	T	T	T	T	T	T	T
bensulide + oxadiazon	NR	T	NR	T	NR	T	T
dithiopyr	T	T	T	T	T	T	T
fenarimol	-	T	-	-	-	-	-
isoxaben	T	T	T	T	T	T	T
metolachlor	T	T	T	NR	T	NR	T
oryzalin	T	T	T	NR	T	T	T
oxadiazon	T	T	NR	T	T	T	T
oxadiazon + benefin	NR	T	T	T	T	T	T
pendimethalin	T	T	T	T	T	T	T
prodiamine	T	T	T	T	T	T	T
pronamide	NR	T	NR	NR	NR	NR	NR
siduron	NR	S	NR	T	NR	T	T
simazine	NR	I-T	T	NR	T	NR	T

T = tolerant; I = intermediate tolerance, use low rates; D = dormant use; NR = not registered for use; S = sensitive.

Appendix D (cont.)

TURFGRASS TOLERANCE TO POSTEMERGENCE HERBICIDES							
	Bahiagrass	Bermudagrass	Centipedegrass	Kentucky Bluegrass	St. Augustinegrass	Tall Fescue	Zoysiagrass
POSTEMERGENCE							
atrazine	NR-I	D	T	NR-S	T	NR-S	I-T
bentazon	T	T	T	T	T	T	T
bromoxynil	T	T	T	T	T	T	T
2,4-D	I-T	T	S-I	T	S-I	T	T
2,4-D + dicamba	T	T	I	T	S-I	T	T
2,4-D + MCPP	T	T	I	T	S-I	T	T
2,4-D + triclopyr	NR	NR-S	NR-S	T	NR-S	T	NR
2,4-D + MCPP + dicamba	I-T	I-T	S-I	T	S-I	T	T
carfentrazone	T	T	T	T	T	T	T
clopyralid	T	T	T	T	T	T	T
clopyralid + triclopyr	I	I	T	T	S	T	T
dicamba	T	T	I-T	T	S-I	T	T
diclofop-methyl	NR	T	NR	NR	NR	NR	NR
DSMA/MSMA	S	T	S	I-T	S	I-T	I
ethofumesate	NR	I	NR	NR	NR	NR	NR
fenoxaprop	NR	NR-S	NR-S	T	NR-S	T	T
fluazifop	NR	S	S	-	S	T	T
foramsulfuron	NR	T	NR-S	NR_S	NR-S	NR_S	I
glyphosate	S	D	S	S	S	S	S
halosulfuron	T	T	T	T	T	T	T
imazapic	S	I	T	S	S	S-I	I
imazaquin	S	I-T	T	S	T	S	T
MCPP	T	T	I-T	T	S-I	T	T
metribuzin	NR-S	I-T	NR-S	NR-S	NR-S	NR-S	NR-S
metsulfuron	S	T	I	I	T	S-I	T
fluroxypyr	--	I	I	T	I	T	I
pronamide	NR	T	T	S	T	S	T
rimsulfuron	NR	T	T	NR-S	NR	NR-S	T
quinclorac	NR-S	I-T	NR-S	T	NR-S	T	T
sethoxydim	NR-S	NR-S	T	NR-S	NR-S	NR-S	NR-S
sulfosulfuron	NR	T	T	NR-S	T	NR-S	T
trifloxysulfuron-sodium	NR	T	NR	NR	NR	NR-S	T

T = tolerant; I = intermediate tolerance, use low rates; D = dormant use; NR = not registered for use; S = sensitive.