Crop Profile for Turfgrass in North Carolina (2004)

Prepared: February, 2004

Production Facts

- North Carolina ranks eighth in the U. S. in total turfgrass acreage.
- There are 2,007,100 acres devoted to turfgrasses in North Carolina.
- Turfgrasses are found in single-family dwellings, roadsides, parks, commercial properties, churches, golf courses, schools, athletic fields, sod farms, airports, institutions, and cemeteries.
- Over $833 million is spent annually to maintain these turf acres.
- The equipment used to maintain the turf is valued at $3.5 billion.
- Single family dwellings account for 61% of the turf area, 56% of expenditures, and 84% of the value of turf related equipment.
- Single-family dwellings, commercial properties, and golf courses comprise 69% of the turf acreage, 87% of annual maintenance expenses, and 96% of the value of turf equipment.
- Golf courses represent 2.6% of the turf acreage, comprise 14% of maintenance expenses, and 5% of the total value of turf equipment.
- North Carolina ranks ninth in total turf acreage on golf courses with 51,700 acres on 531 golf courses.
- Twelve turfgrass species are utilized in North Carolina. They are tall fescue, fine fescue, bermudagrass, centipedegrass, Kentucky bluegrass, bahiagrass, annual ryegrass, perennial ryegrass, zoysiagrass, St. Augustinegrass, carpetgrass, and bentgrass.

Production Regions

Turfgrasses are grown in all 100 counties of North Carolina. Higher maintenance turf such as found in single-family dwellings, golf courses, and commercial property is concentrated in population centers of the state.

Production Practices

North Carolina is situated in the transition zone, which means both cool-season and warm-season turf species can be successfully grown. However, heat tolerance of cool-season species and cold tolerance of warm-season species is an issue for turf managers in the state. Because single-family dwellings comprise the largest percentage of the turf acreage (61%) and

tall fescue is the most common turf species in home lawns, this turf species is grown on 37% (742,600 acres) of the turf acreage in North Carolina. The second most common turf species is bermudagrass, which represents 12.3% of the turf acreage in the state (247,873 acres). Labor is the single biggest expense category totaling $374 million and accounting for 45 % of the total. Equipment supplies and repairs, miscellaneous expenses, and pesticides account for 30%, 21%, and 5% of turf maintenance expenses. On pesticides, $41,973,000 was spent on turf maintenance in 1994. Single-family dwellings accounted for 65%, or $27,158,000, of all pesticide expenditures. Golf courses spent more in terms of dollars per acre on turf maintenance than any other sector. Average turf maintenance expenses on golf courses was $2,243 per acre compared to cemeteries ($1,383), commercial properties ($1,287), institutions ($621), schools ($590), churches ($415), airports ($233), single-family dwellings ($386), roadsides ($83), and parks ($69).

Worker Activities

Home 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, enhance the pesticide’s activity, or remove it from the foliage and thatch and move it into the soil.
- 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 in home and commercial settings. 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 and the worker applying the fertilizer is also the pesticide applicator.

MOWING

- Mowing must be done on a frequent basis and is done at the same time of year as pesticide applications. Mowing of commercial properties is often accomplished with larger mowing units on which the worker rides, but other properties (such as home lawn) may utilize walk behind units.
- Prolonged REIs might influence mowing schedules, but applications could be timed to avoid any problems. Mowing may occur as often as every five days during optimal growing conditions, but few pesticides have REI longer than 24 hours in turfgrass.

AERIFICATION

- Aerification is a cultural practice that occurs during periods of peak 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 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 equipment.

Golf Courses

MOWING

- Essential for maintenance of dense and uniform playing surface.
- Conducted at frequencies ranging from 1 to 7 times per week, 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 and 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 foliar sprays.
- Frequency of fertilizer application ranges from annual to biweekly depending on turfgrass species 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.

CULTIVATION

- Necessary for relief of soil compaction and reduction of thatch accumulations

- Performed one to five times per year, depending on turfgrass species and site use, using a variety of implements.
- Aerification plugs and debris are removed by machine, as a result, there is little opportunity for worker exposure to pesticide residues on foliage or in soil.

Sports Turf

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Sod Production

PLANTING

- Planting of turfgrass on sod farms is typically done either by seed or by vegetative means that would 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.

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 the back.
- 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 is very labor intensive. 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 to palates where the sod is physically placed to be loaded onto trucks. Workers physically handle both turfgrass tissue as well as soil. If pesticides were present, the highest amount of exposure would occur during this process.

Pest Management Strategies

Turfgrass pests include disease pathogens, insects, and weeds. Some pests will always be present; however, what can be considered an acceptable level of pest activity will vary with each situation. For example, a light infestation of broadleaf weeds may be tolerable in a park-like setting but would be unacceptable in a golf green. Defining an acceptable level of pest activity, whether on roadsides, golf courses, home lawns, athletic fields, or parks and grounds must be determined by the individual most familiar with the situation. Measures available to the turfgrass manager for the prevention and control of pest problems include the wise use of pesticides along with management practices that promote a healthy, dense, vigorous turf. Proper management practices can prevent or reduce pest encroachment and development. Rising chemical costs, limited availability of long-term residual pesticides, increased resistance to pesticides, and environmental concerns have emphasized the importance of efficient turf management and reduced dependency on pesticides. Research has shown that a properly maintained lawn is better able to ward off certain diseases and weeds and will tolerate a higher number of insects than a lawn, which is mismanaged. In addition, turfgrass rate of recovery from injury, whether it be pest or nonpest related, is usually faster when the turf has been managed properly.

Site Selection and Preparation

Proper site selection and preparation can help prevent the development of future problems. Good soil and surface drainage can help reduce disease and weed problems. Soil mixtures developed specifically for certain types of turf areas can aid drainage, reduce soil compaction, and provide an environment favorable for good growth. Selective tree removal can limit shade and tree root competition as well as reduce environmental conditions favorable to pest development. Certain diseases such as Pythium blight 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; therefore, 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.

Turfgrass Selection

Turfgrass selection should be based on the existing environment, intended use, and expected management intensity. Check with a turfgrass specialist or extension agent to find out which grasses perform best in a given area. Blends and mixtures should be used whenever possible to insure good performance over a wide range of conditions. Cool-season grasses (bentgrass, bluegrass, ryegrass, fescue) are best established during the fall, whereas warm-season grasses (bermudagrass, zoysiagrass, centipedegrass, St. Augustinegrass) are best planted in late spring or early summer. Use of improved, adapted, turf-type grasses, free of objectionable weeds, 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, and others. Several cultivars are also being marketed that claim resistance to certain insects. Insist on certified seed to assure seed of high genetic purity. Uncertified seed frequently produce plants of low quality that are very difficult to manage. Also insist on seed that is free of weed and crop seed. (Crop seed consists of objectionable and difficult to control perennial grasses.)

Nutrition

Fertilizer programs should meet the nutritional needs of the turf without promoting excessive growth. Specific nutrient needs can be determined with a soil test. (Remember: a soil sample should accurately reflect the existing site.) Soils in intensively managed areas should be sampled every 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. A high rate of nitrogen applied in late summer or fall can make warm-season grasses more susceptible to cold injury and pest infestation. 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 precede the optimum growth period of the grass species. Slow-release nitrogen sources are the best choices for turf grown in sandy soils or near bodies of water.

Irrigation

When irrigating, water should be applied infrequently but deeply. Foot printing, leaf curling, and discoloration are indications that turf needs to be watered. Light, frequent watering encourages a shallow root system, compaction from traffic, and 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 has 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.

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 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 a day or two before a scheduled event. Turf cultivation selective tillage 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 can improve water infiltration and stimulate plant growth but will not be good substitutes for 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 turfgrass (grasscycling). Major causes of thatch accumulation include (1) use of vigorous sod forming turfgrasses; (2) high rates of nitrogen; and (3) frequent use 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 greens. On large or less intensively managed areas, reincorporation of soil cores following aeration, using a drag mat, is an acceptable alternative to topdressing. Light, repeated verticutting is preferred when thatch is excessive. Turfs should be dethatched at a time when the turf can quickly recover. However, overstimulation of plant growth should be avoided. Slowrelease sources of nitrogen are less likely to leach and volatilize in thatchy turf compared to a water-soluble source of nitrogen.

Integrated Pest Management (IPM)

An integrated pest management (IPM) program is a multidisciplinary, ecologically based pest management system that uses all available methods to keep pests at acceptable levels while minimizing the effect on people, the environment, and turf. Pesticides are only one of several options available to managers for controlling pests. Other options include genetic, regulatory, physical, biological, and cultural solutions. A sound IPM program is based on tolerating a level of pest damage, which does not significantly reduce the acceptability of the turf. A sound IPM program will include:

- *A knowledgeable manager*. Knowledge is the cornerstone of any successful IPM program. Managers should know about the grasses being grown, the pests, which are likely to be a problem, and the conditions that may impact the pests and grasses being maintained.
- *A written plan*. This plan should include objectives for each turf area and the degree of acceptable injury from pests. It will help define pest threshold levels. Include in the plan specific management practices for nonchemical control.
- *Definition of pest threshold levels*. Determine what is acceptable for your turf, such as whether weeds should be allowed or how many insects should be tolerated per square foot. Recommendations are available regarding threshold levels for certain insects.
- *Implementation of appropriate cultural practices*. Use of agronomically sound cultural practices results in a healthy, dense, vigorous turf that is better able to ward off pests and pest injury.
- *Monitoring of pest activity*. Most pests are easy to manage when they are immature and few in number. Frequent scouting can help determine the stage of pest activity or injury.
- *Maintenance of accurate records*. Keeping accurate, up-to-date records of pest activity, actions taken, and the results of those actions will assist in future planning.

Pesticides are sometimes necessary to keep pests at tolerable levels. These chemicals will continue to be an integral part of any IPM program. However, sole reliance on chemical control can no longer be justified because of rising chemical costs, increased resistance to pesticides, and environmental concerns. Some pesticides can also enter surface or groundwater either from leaching or runoff. The selection of pesticides to be used on the turf should be based on many criteria including the pest to be controlled; the turfgrass species the pest is infesting; the season and growth stage of the pest; the level of control desired; the application method required for the pesticide; the duration of control from the pesticide; the possibility of

environmental contamination; and the need for frequent rotation of pesticides of different modes of action for the target organism to avoid pesticide-resistant plants, insects, and diseases. After all factors are considered, there may be two or three possible choices of pesticides for control of the pest.

Summary

Damage from turfgrass pests — diseases, insects, and weeds — many times can be controlled at acceptable levels with proper turfgrass management methods. Unacceptable levels of pest damage often indicate a flaw in the current turfgrass management. 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 available biological, cultural, chemical, manual, and mechanical pest control tools. If pesticide use is warranted to maintain acceptable turfgrass quality, the proper selection and use according to the pesticide label is required.

Pesticide Use in Turfgrass

INSECTICIDES AND NEMATICIDES

Home Lawns

Homeowners spend over $5 million on insect control in North Carolina, however this is only about 1% of total maintenance costs. Newer products such as the pyrethroids, imidacloprid, and halofenozide have entered the homeowner market and only in the past two to three years has use been significant. This may be a reflection of the firm grasp that chlorpyrifos, carbaryl, and diazinon had on the market place prior to enactment of the FQPA. Perhaps most importantly, the newer products do not have the broad range of use sites on the label, which allowed homeowners to use these products virtually anywhere around the home. Chlorpyrifos, diazinon, and carbaryl are broad spectrum products with maximum brand name recognition and user familiarity. These products were preferred by homeowners, not only for the above reasons, but also for the fact that they serve such a multitude of uses around the home. Other products such as bendiocarb, trichlorfon and acephate receive some use either as a product that a homeowner has been specifically directed to purchase, in combination with a lawn care product (fertilizer), or as a product of choice for a specific insect problem (e.g., acephate for mound treatment of fire ants), but these are not major uses. Bendiocarb has been phased out and few inventories remain.

Commercial

Insecticide use in the commercial arena relies less upon broad spectrum approaches, but more on addressing specific pest problems and use of the most cost effective product for that need. Thus broad spectrum insecticides are less critical, however, the broad spectrum products do allow commercial applicators to maintain a smaller inventory of products to meet the needs of their operation. Only about 20 to 25% of commercial properties (excluding golf courses) annually treat for insects. Approximately 95% of all golf courses treat for insects each year.

Major pest problems in commercial turfgrass include the white grubs. Recent introductions such as imidacloprid, halofenozide and fipronil have dramatically changed the market composition. Many commercial applicators have embraced these new products for grub control and they now make up a very significant share of the white grub, mole cricket, and fire ant markets. Both imidacloprid and halofenozide must be used somewhat in a prophylactic or preventive mode to ensure product efficacy. This is a challenge in North Carolina since our grub problems are not as consistent as they are in the northeast U.S. A variety of other products are used on the remaining acreage including carbaryl, trichlorfon, carbaryl, and acephate. In general, these products are less expensive than the newer products and are relatively efficacious. The market share for these products is split among the various products with acephate holding a very small percentage of the grub market. Trichlorfon is the product of choice as a rescue treatment for white grub problems due to its high water solubility and rapid action (but short residual activity). Carbaryl is used extensively for one grub species, the green June beetle grub, since it has proven quite cost effective for that pest. Diazinon is no longer labeled for use on turf (other than golf course) and has been phased out due to actions of the FQPA. The other pests complexes such as ants (including fire ants), chinch bugs, caterpillar pests, and mole crickets all have a rather large array of products (including pyrethroids, imidacloprid, halofenozide, and fipronil) available for their management and no one particular product dominates the market (except fipronil is the product of choice for mole crickets if budgets can afford that product).

Pyrethroids have become increasingly popular for the control of many pests particularly the caterpillars and chinch bugs due to the low use rates and the low mammalian toxicity. Chlorpyrifos use is now restricted to golf courses and this has eliminated the most efficacious product for southern chinch bugs and thus more frequent treatments of pyrethroids are often required in the home lawn care market. These include: deltamethrin, permethrin, cypermethrin, bifenthrin, cyfluthrin, and lambda-cyhalothrin. Due to the widespread occurrence of these pest across many crops and the sporadic nature of their pest status on turf there does not appear to be a danger of resistance. Due to the nature of the "crop", cultural practices play only a limited role in reducing insect pest problems. Pest control for the white grubs, mole crickets, and fire ants has been most dramatically as far as loss of the labeled products for those pests due to FQPA.

Fenamiphos (an organophosphate) and ethoprop are products registered for sting nematode control in commercial turf. It is estimated that fenamiphos is used on 5% of the commercial turf acreage and ethoprop is approximately 1%. While only 5% of the acreage is treated with fenamiphos, this use is considered critical for the management of otherwise uncontrollable sting nematodes. Numerous products are under investigation for control of nematodes with turf with current state labels in several southern states for Curfew (same as Telone II) from Dow Agrosciences.

HERBICIDES

Weeds are the number one pest problem for turfgrasses in North Carolina. Of all pest problems, weeds rank first in all segments of the industry with golf courses being the lone exception where weeds are second to diseases. Herbicides are heavily relied upon for weed management in turf due to limited cultural control methods such as crop rotation and cultivation. Preemergence herbicides for crabgrass and goosegrass 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). As with insecticides, herbicides will be broken into two categories: home lawn (homeowner use) and commercial (golf courses, commercial properties, roadsides, and professional lawn care companies).

Home Lawns

Homeowners and tenants spent $18.8 million on herbicides and weed control products in 1994. This represents 4% of total maintenance costs for lawn care but represents 69% of all costs associated with pest control. Weeds rank as the number one turf management problem in home lawns. Over 39% of turf management problems are weed problems. Poor soil (20% of turf management problems) is the second most common turf management problem. Insects and diseases are 2.9% and 0.6%, respectively. Preemergence herbicides represent the majority (>80%) of weed control products in home lawns. These include the DNAs for crabgrass and goosegrass control and atrazine (various trade names) and imazaquin (Image) for preemergence/postemergence broadleaf weed control and annual bluegrass control. In tall fescue, the DNAs are essentially the only preemergence herbicides used whereas in warm-season turf such as bermudagrass, centipedegrass, zoysia, and St. Augustinegrass, imazaquin and atrazine are commonly used for miscellaneous broadleaf and annual bluegrass control. The DNAs are also commonly used in warm-season turf for crabgrass and goosegrass control. Postemergence herbicides are used for remedial weed control in various turfgrass species utilized in home lawns. The only postemergence herbicide available for crabgrass and goosegrass control is sethoxydim (Vantage) for use in centipedegrass and fine fescue. There are many products that are mixtures of herbicides and are mostly used for control of miscellaneous broadleaf weeds. Common combination products include 2,4-D, mecoprop, and dicamba in various concentrations and ratios. These products are routinely available in garden centers.

Commercial

As with home lawns, weed problems generally rank in the top 2 to 3 turfgrass management problems in commercial turf. Because many more herbicides are available to turfgrass managers licensed as commercial applicators, the spectrum of herbicides used in commercial turf exceeds those used by homeowners. In some areas of commercial turf, herbicide use makes up a vast majority of pesticide use.

Weed problems that result in herbicide use include crabgrass and goosegrass which, as in home lawns, still represents the vast majority of preemergence herbicide use. Preemergence herbicides for crabgrass and goosegrass represent approximately 60% of all herbicide use in commercial turf. These include the previously mentioned DNAs (pendimethalin, oryzalin, trifluralin + benefin, benefin (alone)) and dithiopyr and oxadiazon. Postemergence herbicides are also utilized for remedial crabgrass and goosegrass control on approximately 10% of turfgrasses. These are utilized when preemergence herbicide activity is inadequate. Products used for postemergence control in bermudagrass include monosodium methanearsonate (MSMA) and MSMA + metribuzin (Sencor). In cool-season turf, fenoxaprop (Acclaim Extra) is utilized for postemergence crabgrass and goosegrass control. On some sites, fenoxaprop is utilized as the primary means of crabgrass control but in most cases it is still used when preemergence activity is lost. In many cases, herbicides are used with both preemergence and

postemergence activity. These include ethofumesate (Prograss) for annual bluegrass control in cool-season turf (2% of acreage), simazine for winter annual broadleaves and annual bluegrass control (5% of acreage), atrazine for the same weeds (<1% of acreage), imazaquin (5% of acreage), and pronamide (Kerb, 3% of acreage). In industrial turf, particularly roadsides, herbicides make up 98% of all pesticide use. Many industrial herbicides have both preemergence and postemergence activity. Sulfometuron (Oust) is commonly used (90%) for warm-season release on roadsides in North Carolina. Metsulfuron (Escort) also has preemergence and postemergence activity and is used on approximately 15% of industrial turf. Imazapic (Plateau or Imazapic Applicators Concentrate) is used on approximately 5% of industrial turf. Many postemergence herbicides are used in commercial turf. Combination products are also commonly used. These include 2,4-D, mecoprop, and dicamba (various trade names), 2,4-D, mecoprop, and dichlorprop (various trade names), and triclopyr + clopyralid (Confront), and combinations of these products. These postemergence herbicides are used on approximately 25% of commercial turf in North Carolina for control of miscellaneous broadleaf weeds. Glyphosate (Roundup Pro) and glufosinate (Finale) are also used for turf renovation. Each year, approximately 4% of turf acreage gets one of these herbicides.

PLANT GROWTH REGULATORS

Plant growth regulators (PGRs) are becoming increasingly popular turf managment tools in North Carolina. Over 90% of PGRs are used either in industrial turf (seedhead suppression) or highly maintained turf (golf courses). In industrial turf, all PGRs are sublethal rates of herbicides. These include sulfometuron (Oust), imazapic (Plateau or Imazapic Applicators Concentrate), or metsulfuron (Escort). These products are used on 50% of industrial turf in North Carolina. On golf courses, trinexapac-ethyl (Primo) is commonly used (55%) on golf course fairways to reduce vegetative growth and to increase turfgrass quality. On bentgrass putting greens, the predominant PGR used is paclobutrazol (60% of bentgrass greens) for annual bluegrass control. Flurprimidol (Cutless) is also used but less than 5% of bentgrass greens are treated with this PGR.

FUNGICIDES

Diseases are an important pest in all sectors of the turfgrass industry. In North Carolina, the most severe disease problems occur on cool-season grasses (fescues, ryegrasses, bluegrasses, and bentgrasses), which comprise 50% of the turfgrass acreage in North Carolina. Approximately $8.4 million was spent on fungicides for turfgrass disease control in 1999. In most landscape situations, diseases can be managed effectively through selection of resistant varieties and use of proper turfgrass management practices (mowing, fertilization, irrigation, cultivation, etc.). Fungicide use is an essential component of disease management programs in commercial turf because of limited flexibility in grass selection and management practices.

HOME LAWNS

Homeowners and professional lawn care companies spent $2.5 million on fungicides for disease control in 1999. Approximately 90% of fungicide applications to landscape turf is made for control of brown patch and large patch. Both diseases are caused by the fungus *Rhizoctonia solani*; brown patch is specific to cool-season grasses and large patch is specific

to warm-season grasses. The DMI (myclobutanil, propiconazole, triadimefon) and benzimidazole (thiophanate-methyl) classes of fungicides are used most frequently for control of brown patch and large patch. Although these fungicides are weak for *Rhizoctonia* control, they are readily available to homeowners on store shelves. The DMIs and benzimidazoles also remain the fungicides of choice for professional lawn care companies because of product familiarity and relatively low cost per application. New classes of fungicides, such as the QoIs (azoxystrobin, pyraclostrobin, and trifloxystrobin) and benzamides (flutolanil) have not widely adopted in the lawn care sector, primarily because they cost 50 to 100% more per application. However, these products are highly effective for control of *Rhizoctonia* diseases, and research is showing that reduced application rates or extended application intervals provide excellent control in landscape situations. Use of the QoIs and benzamides is expected to increase steadily over the next decade.

COMMERCIAL

In 1999, golf courses spent $5.9 million on fungicides for turf disease control. Over 90% of fungicide active ingredient is applied to putting greens, which comprise 3% of the turfgrass acreage on a typical golf course. Fungicide use is critical for putting green management because of regular mowing at 1/8" or less, frequent traffic, and low tolerance for damage from disease. There is also a limited selection of grasses that are adapted to this environment, and there has been little progress in breeding these grasses for disease resistance. There are many diseases that occur regular on putting green turf, including dollar spot (*Sclerotinia homoeocarpa*), brown patch (*Rhizoctonia solani*), Pythium blight (*Pythium aphanidermatum*), Pythium root rot (*Pythium* spp.), anthracnose basal rot (*Colletotrichum graminicola*), yellow patch (*Rhizoctonia cerealis*), pink snow mold (*Microdochium nivale*), fairy ring (*Basidiomycetes*), algae (*Cyanobacteria*), take-all patch (*Gaeumannomyces graminis*), and summer patch (*Magnaporthe poae*). Because of the broad spectrum of pathogens that must be managed, golf course superintendents must utilize all available classes of fungicides. The availability of a large selection of fungicide classes is also important for prevention of fungicide resistance, which is a common problem in populations of *Sclerotinia homoeocarpa*, *Pythium aphanidermatum*, and *Colletotrichum graminicola*.

Current Pesticide Recommendations for Turfgrass in North Carolina

Current North Carolina Cooperative Extension Service recommendations for pesticide use on turfgrass are provided in the following tables in the *North Carolina Agricultural Chemicals Manual*:

North Carolina Agricultural Chemicals Manuals		
TABLE	**TITLE**	**LINK**
Table 5-19	Commercial Turf Insect Control	**http://ipm.ncsu.edu/agchem/5-19.pdf**
Table 5-23	Insect Control for Home Lawns	**http://ipm.ncsu.edu/agchem/5-23.pdf**
Table 6-14	Turfgrass Disease Control	**http://ipm.ncsu.edu/agchem/6-14and6-15.pdf**
Table 6-15	Nematicides for Turf	**http://ipm.ncsu.edu/agchem/6-14and6-15.pdf**
Table 8-14	Chemical Weed Control in Lawns and Turf	**http://ipm.ncsu.edu/agchem/8-14.pdf**
Table 9-12	Growth Regulators for Turfgrasses	**http://ipm.ncsu.edu/agchem/9-12.pdf**

Insect Pests

Many insects and small animals live in or on turf. Some damage turfgrasses by feeding on or sucking sap from the roots and leaves and, to a lesser extent, stems. Others damage turfgrasses by making burrows in the soil that disturb roots. Insects may reduce stands by killing plants, reduce turfgrass quality, or make plants more susceptible to other pests. Some also transmit plant pathogens. If turfgrass areas have stunted, distorted growth, browning or yellowing leaves, or dead areas, you should confirm the presence of insects before an insecticide is applied. Similar symptoms may be caused by diseases, nematodes, poor soil conditions, or other factors. Potential insect damage to turf varies greatly due to many factors such as fertility, irrigation, height of cut, age of turfgrass, climate, food availability, plant response, natural enemies (parasites, predators, and pathogens), and use of the area. Some turfgrasses are more tolerant of insect attack than others and grow well in spite of insects. Others may be severely damaged by the same number of insects. Fortunately, only a few pests cause problems that require control measures in any given year. Therefore, it is impossible to give a clear-cut guide to the number of insects that must be present to cause damage for each situation. From experience we know that certain insects must be controlled at the first sign of presence because they will likely increase in numbers and cause considerable damage. With other pests, pest buildup can be detected by frequent examination of the turf and insecticides used only if the injury gets progressively worse. Heavy infestations of cutworms, fall armyworms, or sod webworms may be tolerated on fairways, industrial areas, home lawns, and parks with few ill effects, whereas only a few in number severely damage golf greens.

SOIL INSECTS

The major soil-inhabiting insects in North Carolina are the grubs (larvae of many species of beetles such as the Japanese beetle, green June beetle, Asiatic garden beetle, northern masked chafer, southern masked chafer, and billbug), ants, mole crickets, and scale insects such as ground pearls. Soil insects are difficult to detect and can only be found by close examination of the roots, stems, and crowns of plants along with soil from around the turfgrass. This usually requires a shovel or spade to dig up the turf and soil. Moles, birds, and skunks feed on grubs and, in the process, tear up the turf as they search for them, often causing extensive damage.

Control: If an economic threshold of grubs exists, there are now several alternatives to conventional insecticide use. The spores of *Bacillus popilliae,* milky spore disease, for control of Japanese beetle larvae have been around for years. Treatment with milky spore disease is expensive, very slow, and should only be directed against Japanese beetle grubs. However, once the spores are distributed, the treatment will provide some control for years. Unfortunately, there are no data to support the effectiveness of milky spore, and the availability of quality product has been sporadic in recent years. New products such as various species of entomogenous nematodes that are currently available and a new strain of *Bacillus thuringiensis* that is effective against white grubs have provided and will provide future opportunities for alternative management options. Timing and application techniques are critical with these control options. Insecticides must be distributed evenly to obtain good insect control. They may be applied as coarse sprays or granules. Because effective control depends upon contact between the insect and the insecticide, the treated area should be irrigated immediately after application. With sprays, this is before spray deposits dry. Granules should

be applied when the grass is dry. At least ½ inch of water should be applied as soon as possible. This is important because some insecticides have a strong affinity for organic matter, and some of the material binds to the thatch and becomes ineffective unless sufficient water is used to drench the material through the thatch. Some insecticides are virtually impossible to move through the thatch and as a general rule, thatch significantly hinders attempts to manage soil insect pests. Recent research has demonstrated that a pretreatment irrigation is usually beneficial as it adds moisture to the organic matter and aids movement of the pesticide to the target site and also helps move the soil pests closer to the surface.

White Grubs
[Family Scarabaeidae]

White grubs are the larvae of several kinds of scarab beetles. The Japanese beetle larva is the most important species in North Carolina. Other common species are the green June beetle, northern and southern masked chafers, and the black turfgrass ataenius. All have creamy, blunted bodies with yellow to brown heads and brownish hind parts and visible legs (except billbugs).

Mature grubs vary from ¼ to 1½ inches in length depending on the species. White grubs usually lie in a curled or C-shaped position. All of the important species in North Carolina have a one-year life cycle and spend about 10 months in the ground. In mild weather they are 1 to 3 inches below the surface; in winter they go deeper into the soil. All species of grubs other than the green June beetle and billbug larvae burrow around and feed on grass roots about 1 to 2 inches below the surface. Heavy infestations destroy the root system and cause the area to become "spongy." The turf can often be rolled back like a carpet. Damage is most apparent in April and May or September and October when grubs are actively feeding. All species of turfgrasses are affected, but injury is more severe on bluegrass and bentgrass. Moles, skunks, and birds feed on grubs and often severely damage turf areas while searching for them. The green June beetle grub feeds mainly on decaying vegetative matter. Grass is smothered by mounds of dirt as a result of burrowing. They also uproot seedlings. Sometimes in the fall or after a heavy rain, green June beetle larvae come out of the soil and crawl on the surface of the ground. They have the unusual habit of crawling on their backs. This pest seems to be on the increase throughout North Carolina and the southeastern United States. Billbugs (not a true white grub) feed on stems, crowns, and rhizomes and severely weaken the turf and deposit a sawdust-like grass. Adult beetles usually appear from mid-May to mid-June depending on the species and weather conditions. They are usually active from 4 to 6 weeks, during which time eggs are laid for succeeding generations.

Control: To detect white grubs, take 1-square-foot areas from several locations and examine the soil and roots in the top 3 to 4 inches. If an average of five or more grubs is found per square foot, apply an insecticide for control. The condition of the turf, its value, use, and damage caused by birds and mammals may alter thresholds. Control of white grubs can be difficult, and there will probably always be some level of activity in the soil following treatment. Insecticides are most effective if applied when grubs are small and actively feeding and soil temperatures are warm (August and September). It is important to remember that some grubs have different life cycles. Billbugs and black turfgrass ataenius have more than one generation per year. Understanding their development and targeting control toward the most susceptible stages are critical.

Mole Crickets
[*Scapteriscus* species]

Mole crickets are light-brown crickets about 1½ inches long with short, stout forelegs and shovel-like feet. They feed at night on the roots of grass, and their burrowing also uproots seedlings and causes soil to dry out quickly. One mole cricket can travel and damage several yards of a newly seeded area or a golf green in a single night. On golf greens, the raised tunnels made by mole crickets are skimmed off by the mower, damaging not only the grass but also the equipment. Two species are responsible for much of the damage in the southeastern United States. The tawny mole cricket is the most destructive since it feeds almost entirely on the roots of grass; the southern mole cricket that feeds less on grass roots acts more as a predator. Mole crickets generally overwinter as nymphs or adults deep in the soil, but may come to the surface and do some feeding even during the winter months. They become active in March and feed aggressively until they mate and lay eggs in late spring. Each female lays 35 to 50 eggs, which hatch in 10 to 40 days depending on temperature. This egg hatch usually begins in mid- June in North Carolina and continues into July. There is only one generation per year.

Control: Mole crickets are most effectively controlled soon after they hatch. As mentioned above, this usually occurs in North Carolina about mid-June to early July and a little earlier in more southern areas. The smaller nymphs are more susceptible to treatments and at that time of year have not caused serious damage. Under severe insect pressure, even the best-timed treatment may not be sufficient to prevent undesirable damage. Continued monitoring of the area is required, and follow-up treatments should be applied as necessary to those areas still infested, using contact insecticides or poisoned baits. Mole crickets are best monitored by using a soapy water flush (two teaspoons of liquid dishwashing detergent in two gallons of water poured over a square yard area) to detect the small crickets. On established turf, spray or granular applications can be used as long as they are thoroughly watered into the grass. Such treatments will be most effective if they are applied when night temperatures are at least 60°F. Baits can also be effective in August or September but provide little residual activity. For specific chemical controls, consult the state Cooperative Extension Service recommendations. Effective management of mole crickets requires a complete management plan and a commitment to follow through.

other related links:

Ants
[Family Formicidae]

There are a number of different kinds of ants that build nests in the ground on golf courses. They are particularly troublesome when nests are built around the fringes or on golf greens and tees or in fairways. Ant hills and mounds often smother the surrounding grass. Ants also destroy roots of grass near mounds, eat grass seeds, and complicate mowing operations. Some ants bite people and animals -- fire ants and harvester ants are especially vicious. Some people are allergic to imported fire ant bites. Other ants are simply a nuisance.

Control: Ants may be controlled by treating individual mounds with insecticidal drenches or granules. If ant hills are numerous, a broadcast treatment of the entire area may be needed.

Fire ant management is more complicated and requires a complete plan if many mounds are present over a large area.

Bees and Wasps
[Family Andrenidae, Vespidae, Scoliidae and Sphecidae]

There are several species of bees and wasps that occasionally damage turfgrass by digging up the soil, making holes, or forming mounds. Some of these are solitary ground nesting bees, cicada killer wasps, Scoliids, yellow jackets, and bumblebees. Most are present from June to October.

Control: Yellow jackets, bumblebees, and cicada killer wasps will sting if molested. This makes control of these pests important. Spot treatment or broadcast application of recommended insecticides will usually control these insects. The solitary bees, such as the Colletid or Andrenid bees, are not aggressive, but often occur in large numbers in the spring, building nests in areas where the turf is thin. One effective management strategy for many of these bees and wasps is to maintain a thick, lush stand of turf as well as to replenish mulch to keep to a minimum the bare soil areas where the insects prefer to build nests.

Scale Insects
(both soil and surface)
Bermudagrass Scale [*Odonaspis ruthae*]
Ground Pearls [*Margarodes* species, *Eumargarodes* species]

Scale insects suck the juice from grasses — some feed on the crown of the plants and above-ground parts and others feed on the roots. The grass becomes yellow and then brown, and finally dies. Damage is usually more severe in dry periods than in wet. Several kinds of scales damage turfgrass in the southern part of the United States. The most important species of scales are the following:

Bermudagrass Scale: The adults are about 1/16 inch long, oval, and covered with a white, hard secretion. This insect infests bermudagrass and is especially active in shady areas. It kills the grass and leaves bare brown patches.

Ground Pearls: The female adult secretes a white, waxy sac in which it places about 100 pinkish-white eggs. Slender nymphs hatch and feed on the fine grass roots. The nymphs cover themselves with hard globular shells that look like tiny pearls. These are called ground pearls.

They are about 1/8 inch in diameter. Ground pearls cause serious damage to centipedegrass and St. Augustinegrass and, to a lesser degree, bermudagrass. The grass turns brown in the summer; it dies in the fall and leaves irregular dead spots.

Control: Practice good management. Irrigate regularly during dry periods. Control with insecticides is not currently effective.

SURFACE FEEDING INSECTS

Several insect pests, the foliar feeders, feed on turfgrasses at or above the soil surface. One group chews the sides of blades or chews entire plants off at the crown. Examples are armyworms, cutworms, and sod webworms. Another group of insects damages turfgrasses by

sucking fluids from the grass plants. Examples are leafhoppers, spittlebugs, and chinch bugs. Surface-feeding insects hide in grass and burrow into thatch and debris above the soil. This often makes them difficult to locate. The presence of foliar feeders such as sod webworms, armyworms, and cutworms can be verified by mixing one tablespoon of 1 or 2 percent pyrethrum in a gallon of water and applying it to 1 square yard of turf. The soapy water flush mentioned in the "Mole Crickets" section can be substituted if pyrethrum is unavailable. These mixtures irritate the insects and force them to crawl to the surface within 5 to 10 minutes. This technique is not effective for soil insects other than mole crickets. To detect chinch bugs, remove both ends of an empty can and push one end 2 to 3 inches into the turf where chinch bugs are suspected. Fill the can with water and wait a few minutes. If chinch bugs are present, they will float to the surface.

Control: Surface-feeding insects are usually less difficult to control than those in the soil. However, with the exception of control measures for the chinch bug, insecticides should be applied as a spray with little or no irrigation or rainfall within 24 hours. Insecticides should not be applied unless the insect, damage, or both have been confirmed. As a general rule, it is important not to mow and remove clippings for two or three days after treating for surface-feeding insects. Several products are available that offer alternatives to conventional insecticides for surface pests. These include numerous entomogenous nematode products, several *Bacillus thuringiensis* (Bt) products, azidirachtin (neem seed extract), and the lower-use-rate synthetic pyrethroids.

Armyworm [*Pseudaletia unipuncta*]
Fall Armyworm [*Spodoptera frugiperda*]

The fall armyworm is a sporadic but serious pest of turfgrasses in North Carolina. When numerous, this insect will devour grasses down to the ground, causing circular bare areas.

The fall armyworm is 1½ inches long and greenish with blackish stripes along each side and down the center of the back. It has a distinct inverted "Y" on the head. The fall armyworm does not overwinter in North Carolina, but egg-laying armyworm moths migrate northward from Florida and the Gulf Coast areas throughout the spring and summer and begin to arrive in North Carolina in June. Damaging larval populations usually occur from midsummer to late fall. Some years the fall armyworm is a serious pest of turfgrasses in North Carolina, usually following cool, wet springs, which seem to reduce the effectiveness of naturally occurring parasites. Each female lays about 1,000 eggs in masses of 50 or more. Fall armyworms feed any time of day or night, but they are most active early in the morning or late in the evening. When abundant, fall armyworms eat all available food and move in mass to adjoining areas. The larvae feed two to three weeks and a generation takes about five to six weeks. Several generations occur each year. The fall armyworm is a common pest of newly seeded stands of cool-season turf in the fall and often attacks overseeded areas of warm-season grass as the ryegrass establishes. The true armyworm is similar in appearance but lacks the inverted "Y." It is found less frequently in turf but is a potential pest. Larval populations usually occur earlier in the spring and summer.

Control: Armyworms attack most common turfgrasses grown in North Carolina. Chemical control is needed if natural enemies do not keep infestations below the economic threshold of one per square foot on general turf or one per square yard on golf greens. If possible, do not mow turf and remove clippings for several days after treating for any of the caterpillar pests.

Cutworms
Black Cutworm [*Agrotis ipsilon*]
Granulate Cutworm [*Feltia subterranea*]
Variegated Cutworm [*Peridroma saucia*]

Cutworms are the larvae of several species of night-flying moths. The most common species attacking turfgrass in North Carolina is the black cutworm. The variegated cutworm and granulate cutworm also are occasional pests. Each cutworm differs slightly from the others in details of habits and appearance, but life histories are generally similar. Cutworms are fat, smooth, dull-colored caterpillars from 1½ to 2 inches long when full grown. Adults and larvae hide during the day but may become active on cloudy days. Cutworms overwinter in the soil either as pupae or mature larvae. In the early spring, the hibernating larvae pupate and adults appear by mid- March. Females lay eggs singly or in clusters. Eggs hatch in 3 to 5 days, and larvae develop in 3 to 4 weeks. Some have as many as four generations per year in North Carolina. Cutworms feed on leaves or cut off the grass near the soil. They are major pests of bentgrass golf greens and often migrate onto greens from surrounding areas. The grass is often eaten to ground level around aerifier holes or holes made by the cutworms. Cutworms are seldom numerous enough to damage tees, fairways, roughs, lawns, or other turfgrass areas. Damage to turf from cutworms can occur from March to November in North Carolina.

Control: To detect cutworms, closely examine for damage and worms late in the afternoon or use the flush method described under "Surface-feeding Insects." Apply a recommended insecticide if damage is noted and one or more cutworms is present per square foot of general turf. On golf greens, treatment should be applied when one cutworm is present per square yard. Control is generally better if insecticides are applied in the late afternoon.

Sod Webworms
[Family Pyralidae]

Sod webworms are the larvae of the buff-colored lawn moth. The larvae are from ½- to ¾-inch long when full grown. They have dark heads and most are hairy with two dark spots on each body segment. The adults are small, whitish moths that fold their wings closely about the body when at rest. They hide in shrubbery or other sheltered spots during the day. Females fly over the grass in the early evening and scatter eggs on the grass. Moth flights may occur from May to October. The worms live in a protective silken web and work only at night. As larvae grow, they build silk-lined tubes close to the surface of the soil. Several different species of sod webworms infest turf in North Carolina. They attack bentgrass, bluegrass, fescue, hybrid bermudagrass, and other grasses. Larvae cut off grass blades just above the thatch line, pull them into their tunnels, and eat them. Irregular brown spots are the first signs of damage. A heavy infestation will destroy large areas of grass. Most sod webworms complete two to three generations per year in North Carolina, with approximately six weeks elapsing from egg laying to adult emergence. A burrowing sod webworm (*Acrolophus* sp.) occasionally attacks golf greens and lawns in North Carolina. This larva makes a hole about the size of a pencil as much as a foot or more deep that is silk lined. The larva comes to the surface to feed. Damage is usually more prevalent on tall fescues in very dry weather.

Control: If five or more sod webworms or two or more burrowing sod webworms are found in a square foot area, chemical control is recommended.

Chinch Bugs
[*Blissus* species]

At least two species of chinch bugs are pests of turf in North Carolina. The hairy chinch bug is a pest of fescues and bluegrasses in the mountains. The southern chinch bug is a serious pest of St. Augustinegrass in the eastern part of the state. The latter also attacks centipedegrass and, to a lesser extent, bermudagrass. Adult chinch bugs are about 1/6 inch long; they are black with white markings. Young nymphs are about half the size of a pinhead; they are bright red with a white band across the back. The full-grown nymph is black and has a white spot on the back between the wing pads. Most damage is done by the nymphs, which feed for two to six weeks depending on weather conditions. Yellowish spots appear and then rapidly turn brown and die. Damage occurs in scattered patches.

Control: Chinch bugs are serious pests on St. Augustinegrass, and controls are often needed. However, chemical controls are seldom needed on other turfgrasses unless 25 or more chinch bugs are present per square foot. Insecticides need not be watered in (unless stated on the insecticide label) because chinch bugs are found in the upper thatch area. Frequent irrigation is often an effective control of chinch bugs because it helps induce a fungal disease of this pest. Several resistant cultivars have been released.

Leafhoppers and Spittlebugs
[Family Cicadellidae and Cercopidae]

Many species of leafhoppers (small wedge-shaped insects) suck the sap from leaves and stems of grass. Symptoms include a bleaching or drying out of the grass. New fairways, golf greens, lawns, and other turf areas may be seriously damaged so that reseeding or resprigging is necessary. However, established lawns may also be damaged. Spittlebugs attack clovers and grasses. They suck juices from leaves and stems, especially in areas with dense growth and heavy mats of thatch. The spittlebug nymphs live within a mass of white froth or "spittle" which is found on the plants. These insects are often controlled when thatch is removed. Some adults may attack ornamentals while the nymph stage attacks turf. The twolined spittlebug nymphs frequently feed on centipede while the adults are pests of hollies.

Control: Control measures are seldom necessary but may be required on newly established turf.

Bermudagrass Mite
[*Eriophyes cynodoniensis*]

The bermudagrass mite is now found throughout the southern United States. It feeds only on bermudagrass and is a very small, worm-like, white mite about 1/100 inch long. They can only be seen with a good-quality hand lens. However, the damage is easily recognized. First, the grass has yellow tips and then shortened internode and leaves, which produces a rosetted or tufted appearance referred to as "witch’s broom." Infested areas may die, and damage is most severe during hot, dry conditions. These mites are most active during late spring and summer. They spend all of their lives under the leaf sheath.

Control: Bermudagrass mites can be controlled with chemical insecticides, but repeated applications may be necessary. Good management through fertilization and irrigation can help the grass outgrow the mite damage. Resistant cultivars are available.

Weeds

Weeds are plants growing where they are not wanted. They can disrupt the appearance and use of lawns, recreational areas, and other turfs. In addition, they strongly compete with desired turfgrasses for space, water, nutrients, and light. Turf weeds may be grasses, grass-like plants, or broadleaf plants. They may be annual, biennial, or perennial in life cycle. Turf managers should become familiar with weed characteristics, growth habits, spread, and life cycle. These factors play an important role in weed identification and control. A weed management program is based upon identifying the desired turfgrasses and existing weeds, including knowledge of other weeds that may potentially germinate. However, an effective program begins with a vigorous turf, one that has been correctly fertilized, watered, and mowed. Weeds quickly invade thin turf. Cultural and management practices that enhance turfgrass growth generally reduce weed competition and encroachment. When selecting a herbicide, consider the weeds present, those that will potentially germinate, and the tolerance of the turfgrass.

GRASSY WEEDS

Weedy grasses are classified as summer annuals, winter annuals, and perennials. Annuals complete their life cycles in one season by flowering, maturing seed, and dying. Their high seed production serves as a ready source for infestation when conditions are favorable. Summer annuals germinate from late March through July, depending on the location. They flower in the summer and either die in the fall or are killed by frost. Winter annuals germinate in the fall and early winter and usually die with warm weather in the spring or summer; however, they may continue to grow into early summer in cool seasons. Perennials live more than two years and may produce seed each season.

Weed Management Practices

Selection of adapted turfgrass species and cultivars and the use of cultural practices are important in minimizing weedy grass encroachment and competition. Management practices include (1) mowing at the recommended height for the selected turfgrass and removing clippings when seedheads of grassy weeds are present; (2) applying the proper amount of nitrogen at the correct time according to the turfgrass present; (3) using soil tests to determine needed nutrients and lime; and (4) applying preemergence herbicides before weeds germinate. Specific comments relating to selected weedy grasses are included in the following paragraphs.

Crabgrass
Large Crabgrass [*Digitaria sanguinalis* (L.) Scop]
Smooth Crabgrass [*Digitaria ischaemum* (Schreb.) Muhl.]

Crabgrass germinates from March through early May when soil temperatures reach 53°F to 58°F near the soil surface. Alternating dry and wet conditions at the soil surface in the spring encourages germination. Crabgrass germinates and grows best when adequate light and moisture are present. Stems have a prostrate growth habit and may root at the lower nodes. It will grow under close mowing conditions. Crabgrass competition is enhanced by thin, open turfgrass stands; improper mowing heights for the desired turf; summer fertilization; and light, frequent irrigation. For crabgrass control, practice procedures outlined to maintain a dense,

actively growing turf. In areas where there is a crabgrass history, apply a preemergence herbicide in the spring when soil temperatures approach 50°F, which corresponds to about the time that forsythia blooms in North Carolina. These herbicides may be used effectively on home lawns, athletic fields, golf fairways, and parks; however, extreme care should be used when applying them to golf course greens because of variable management practices and turf tolerance. A second preemergence treatment eight weeks after the initial application may be necessary to maintain season-long control of crabgrass. Arsonate herbicides (DSMA, MSMA, CMA) or Acclaim Extra may be applied postemergence for control of emerged crabgrass early in the summer in certain turfgrasses. Because turfgrasses vary in tolerance to preemergence and postemergence herbicides, check labels for tolerance information.

Goosegrass
[*Eleusine indica* (L.) Gaertn.]

Goosegrass germinates when soil temperatures reach 60°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 and cool-season turfgrasses during summer months and is most competitive in thin, open turfs and turfs subject to intense traffic or use. Close mowing, frequent watering, and compaction enhance goosegrass competition. It is a very troublesome grassy weed in athletic fields, golf greens, tees and fairways, and in other turfgrasses that are mowed short. A severe goosegrass infestation may indicate the need for aerification to alleviate compaction. Preemergence herbicides used for crabgrass control are less effective on goosegrass although the level of control is not as good as with crabgrass. Goosegrass may also be controlled by postemergence application of an arsonate herbicide mixed with Sencor or Illoxan (golf courses only) in bermudagrass.

Annual Bluegrass
[*Poa annua* ssp. annua and ssp. reptans]

Annual bluegrass is a light green bunch-type to slightly spreading winter annual weedy grass. Some subspecies exist which are classified as short-lived perennials (*Poaannua* spp. reptans). These perennial types are particularly evident in bentgrass golf greens. Management practices encouraging the persistence of annual bluegrass are (1) excessively close mowing; (2) shallow, frequent irrigation; (3) poor soil drainage; (4) improperly timed fertilization; (5) aerifying or dethatching during primary periods of annual bluegrass germination; (6) use of heavy equipment causing compaction; and (7) shade. Preemergence herbicides applied in the fall before annual bluegrass emerges give effective control in home lawns, athletic fields, and golf course fairways. However, many preemergence herbicides prevent seeding of cool-season turf species in home lawns or overseeding on golf courses. 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.) Preemergence herbicides do not appear to be effective on the perennial subspecies; however, evidence exists that long-term use of some plant growth regulators may shift the competition in favor of the bentgrass over the perennial subspecies of annual bluegrass. Therefore, a well-planned program involving plant growth regulators may increase the bentgrass/bluegrass ratio in putting greens.

Barnyardgrass [*Echinochloa crusgalli* (L.) Beauv.]
Yellow Foxtail [*Setaria glauca* (L.) Beauv.
Green Foxtail [*Setaria viridis* (L.) Beauv.]

Other summer annual grasses, including barnyardgrass, yellow foxtail, and green foxtail, may be controlled by preemergence herbicides. These grasses occur infrequently in North Carolina in highly maintained turf but can be common in utility turf, such as along roadsides.

Annual Ryegrass
[*Lolium multiflorum* Lam.]

Annual ryegrass is a common weed problem in turfgrasses on roadsides in the southeastern United States. It may be controlled by preemergence herbicides when applied before seed germination in the fall. In dormant bermudagrass it may be controlled also with postemergence applied herbicides. Herbicide resistance to certain postemergence herbicides is a major concern.

Dallisgrass [*Paspalum dilatatum* Poir.]
Field Paspalum [*Paspalum laeve* Michx.]
Thin (or Bull) Paspalum [*Paspalum setaceum* Michx.]

This group of paspalums resemble each another very closely, and field paspalum and thin paspalum are often mistakenly called dallisgrass. All three are perennials and management is the same. They are common and are some of the more difficult-to control weeds in turfgrasses. The only proven way to selectively remove this group of paspalums is multiple applications of arsonate herbicides in the early spring in tolerant turfgrass species.

Dallisgrass
Annual Blue-eyed Grass
[*Sisyrinchium rosulatum* Bickn.]

This grass is a winter annual with flattened leaves that cluster at the base of the plant. It resembles goosegrass when it is small but germinates in the fall and produces an attractive small blue or purple flower in the spring. This weed prefers moist sites and only occurs in the southern United States west to Texas and Arkansas. Annual blue-eyed grass can be unsightly when it occurs in dormant warm-season turf.

Sandbur
[*Cenchrus* spp.]

Sandbur can be a very troublesome weed in warm-season turf species. It is easily identified by the seedhead, which is a spike of tiny burs. Preemergence crabgrass herbicides offer fair control of this weed. Arsonate herbicides are effective in tolerant turf species if applied when sandbur is in the seedling stage.

SEDGES

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. It is important to properly

distinguish sedges from grasses because management is totally different. In North Carolina, about 10 species of sedges can be found in turfgrasses. 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 species) that represent new weed problems and 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 a sedge planted from the managed turfgrass area and place it in a pot to allow seedheads to develop. Many sedge species can be problematic in turf. As a general rule, sedges are more of a problem in warmer climates than cooler climates. Proper identification and an understanding of the biology of sedges are necessary for effective management. Sedges are plants that 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. Sedges often become established in wet areas and spread to other areas that are not poorly drained or wet areas. Therefore, it is important to recognize areas where sedges can become established and prevent spread of these sedge species to other areas of the golf course or landscape.

Yellow Nutsedge
[*Cyperus esculentus* L.]

Yellow nutsedge is a native of North America and is found throughout the United States and is one of the more cold-tolerant sedge species. Yellow nutsedge is a rapidly spreading perennial that forms brown- to tan-colored tubers at the tips of rhizomes. It gets its name from the yellowish-brown or straw-colored seedhead. This weed can be a severe problem in both warm- and cool-season turf species. Although this weed can be difficult to control, it is much easier to control than other sedge species. Proper identification is important to obtain effective control. Timing of control strategies is also important. Control strategies should begin in the spring after maximum shoot emergence but before new tuber production. Beginning in late June and early July, this weed species starts to add new tubers, which will lead to additional weed problems in future years.

Purple Nutsedge
[*Cyperus rotundus* L.]

Purple nutsedge is a native of India and is widely distributed in temperate and tropical regions of the world and is not as cold tolerant as yellow nutsedge. In the United States, it can be found in the southeastern part of the country west to the eastern part of Texas and can also be found in parts of California and Arizona. As a result, this weed tends to be more of a problem in warm-season turf. As with yellow nutsedge, purple nutsedge is a perennial that produces tubers on rhizomes. However, there are several ways the species can be distinguished. Purple nutsedge produces tubers in chains connected by rhizomes, whereas yellow nutsedge only produces tubers at the tips of rhizomes. Purple nutsedge tends to have darker green leaves and produces a characteristic reddish-purple seedhead. The leaf tips of purple nutsedge tend to be more blunt than those of yellow. As with yellow nutsedge, control strategies must begin in the spring after maximum shoot emergence but before new tuber production. (In North Carolina, this will be May and June.) This species is much more difficult to control than yellow nutsedge, and effective management will require multiple herbicide applications per year and will likely require several years to successfully control heavy infestations.

Kyllinga Green Kyllinga [*Kyllinga brevifolia* Rottb.]
False Green Kyllinga *[Kyllinga gracillima* Miq.]

These two species are very similar in appearance and both are referred to as green kyllinga. Both species are native to Asia and are spreading rapidly in turfgrasses in the southern United States. Both species are perennials and have well-developed rhizomes. They tend to be shorter growing and have a finer leaf texture than other sedges. They tend to thrive under close mowing (½ inch or less) and are very prolific in areas that are poorly drained or frequently wet. These two species are mat-forming sedges and have been observed to take over turfgrasses in the southeastern United States. Green kyllinga is very difficult to control once the large mats tend to form. The range of these two species is somewhat misleading because they are spreading rapidly. Currently, *K. brevifolia* can be found in North Carolina and states south and west to Eastern Texas and Oklahoma. Several specimens have been collected in California. *K. gracillima* has been found in Tennessee, Alabama, Georgia, North Carolina, Virginia, and Pennsylvania north to Connecticut. 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 arsonate herbicides have significant activity. Therefore, when the arsonate herbicides were regularly used for crabgrass control, these two sedge species were probably prohibited from becoming established. Current control recommendations include multiple applications of arsonate herbicides in tolerant turfgrasses.

Annual Sedge
[*Cyperus compressus* L.]

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. Annual sedge has a very characteristic seedhead that tends to be relatively large compared to other sedges, and the seedhead is flattened with a toothed outline. Annual sedge tends to have a more "clumpy" appearance than other sedges — particularly when it occurs in low densities. This sedge also 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.

Globe Sedge
[*Cyperus croceus* Vahl.]

Globe sedge is a perennial that has a rounded or "globe-shaped" seedhead — hence the name. This species is found from Virginia south into Florida and west to Texas, Oklahoma, and Missouri. It is also found in many of the tropical regions of the world. As with other perennial sedges, multiple herbicide applications are usually necessary for effective control. Care should be taken to prevent this sedge from producing seedheads because spread of this weed is primarily due to seed dispersal.

TURFGRASSES AS PERENNIAL WEEDY GRASSES

Desirable turfgrasses may be classified as perennial weedy grasses. Tall fescue in a bermudagrass lawn would be considered a weed. Most turfgrasses are difficult to control within another turfgrass. Therefore, turf managers should select clean seed or vegetative sources for

establishment, use an adapted turfgrass species and cultivar for their location, and use proper mowing and fertilization techniques to maintain a dense, actively growing, desired turf. Digging or removal with hand or mechanical equipment (for example, a sod cutter) is one way to control undesired perennial turfgrasses. You may spot treat an infested area with an appropriate non-selective herbicide, realizing it will also kill the desired turfgrass.

Bahiagrass
[*Paspalum notatum* Fluegge]

Bahiagrass is easily recognized by the characteristic "Y" shape of the seedhead. It is 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. Control practices are the same as those discussed for the previously mentioned paspalums.

Perennial Ryegrass
[*Lolium perenne* L.]

Perennial ryegrass is often overseeded to provide winter color in warm climates where turf is utilized in winter months. When warm weather prevails in late spring or early summer, this species usually will not survive. However, in the transition zone, especially during cool summers, wet summers, or both, perennial ryegrass can survive the summer and often becomes clumpy. This very attractive turf species becomes a difficult-to-control weed in these conditions. Control strategies should concentrate on controlling perennial ryegrass before it becomes clumpy.

WINTER ANNUAL BROADLEAF WEEDS

Winter annual broadleaf weeds germinate in the fall or winter and grow during any warm weather, which may occur in the winter, but otherwise remain somewhat dormant during the winter. They resume growth and produce seed in the spring and die as temperatures increase in late spring and early summer. They quickly invade thin turf areas especially where there is good soil moisture. Shade may also encourage growth. Many have a prostrate growth habit and are not affected by mowing. Under close mowing in golf greens, common chickweed and mouseear chickweed will survive, forming dense patches which crowd out the desirable turfgrass. Parsley-piert and spurweed also survive the close mowing of greens. Frequent watering encourages chickweed growth.

WEED MANAGEMENT PRACTICES

A dense, vigorous turf is the best way to reduce the encroachment of winter annual weeds. First, select adapted turfgrass cultivars for your area and then properly fertilize, mow, and water to encourage dense growth. Watering scheduled to meet turfgrass needs helps to minimize chickweed competition. All of the winter annual weeds described in this section except corn speedwell may be controlled with selective broadleaf postemergence herbicides if the desired turfgrass has tolerance. When controlling several different weeds, it may be desirable to select a combination product, which is a mixture of two or three broadleaf herbicides. For corn speedwell, repeated applications of a threeway combination product at

one half the label rate applied 10 days apart provide good control. This treatment is also effective on parsley-piert and spurweed. In dormant bermudagrass golf fairways, several herbicides which have both preemergence and postemergence activity may be applied to control winter annual broadleaf weeds and annual bluegrass. Also, non-selective postemergence herbicides are available for controlling these weeds in completely dormant bermudagrass. Winter annual broadleaf weeds are preferably sprayed from February through April depending on the turf, location within the state, temperature, and growing conditions. In warm-season turfgrasses, winter annual broadleaf weeds should be sprayed while the turf is still dormant and before spring green-up occurs. Spray before resumption of spring growth in cool-season turfgrasses. By spraying at these times, the turf has a greater chance of growing into those previously weed infested areas. Certain preemergence herbicides may be used to control chickweed in areas where reseeding or overseeding of turf is not planned. These are applied in the fall prior to expected germination of chickweed, which is encouraged by cool temperatures and adequate moisture.

Hairy Bittercress
[*Cardamine hirsuta* L.]

Hairy bittercress is a winter annual with erect stems about 3 to 9 inches tall. 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 ¾ inch long and 1/32 inch wide.

Buttercups
***[Ranunculus* species]**

Two of the common winter annual buttercups found in the state are hairy buttercup *[Ranunculus ardous* Crantz] and bulbous buttercup *[Ranunculus bulbosus* L.*]*. Hairy buttercup appears to be predominant in the piedmont and mountain regions, while bulbous buttercup is readily found in the piedmont and coastal plain regions. Hairy buttercup is a hairy plant with erect, hairy stems (single or branching from the base) and a fibrous root system. The leaves are attached to long petioles, palmately three-lobed and also 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. Vegetative characteristics of bulbous buttercup are similar to hairy buttercup except for the bulb-like swelling at the base of the stem. This swelling is roundish and white, slightly flattened at the top and bottom, and somewhat resembles a small turnip.

WEEDS IN TURF

Common Chickweed
[*Stellaria media* (L.) Cyrillo]

Common chickweed is a low-spreading winter annual with a weak, shallow root system. The prostrate stems often root at the nodes. Its spreading growth covers adjacent turf and seriously impedes turf growth. Chickweed often forms extensive, dense patches. Leaves are opposite, oval in outline, and tapered to a point. 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. The plant produces numerous seeds, which germinate from late fall through early spring.

Mouseear Chickweed
[*Cerastium vulgatum* L.]

Mouseear chickweed acts as a winter annual in eastern North Carolina and as a perennial in the western part of the state, especially at higher elevations. It has a vigorous prostrate growth habit. Leaves of mouseear chickweed are opposite, oblong, dark green and, in contrast to common chickweed, covered with soft hairs. Hairy stems may creep along the ground and take root at nodes touching the soil. The small, white flowers have five slightly notched petals.

Large Hop Clover
[*Trifolium campestre* Schreb.]

Large hop clover is a much branched winter annual weed. It has a trifoliate leaf similar to white clover. Leaflets have prominent veins and the terminal leaflet of each leaf is on a short stem. Hop clover has short, hairy, reclining, slender stems, which are somewhat reddish. Flowers are bright yellow with numerous closely associated flowers borne in clusters. Each individual flower produces a single seed. Small hop clover [*T. dubium* Sibth.] is very similar, but with fewer flowers in the cluster.

Carolina Geranium
[*Geranium carolinianum* L.]

Carolina geranium is a winter annual that is also called cranesbill because the fruits have a conspicuous "" beak about ½ inch long. The leaves are deeply five- to seven-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. It blooms mostly in April and May.

Henbit
[*Lamium amplexicaule* L.]

Henbit is a very common winter annual weed in turf. Stems grow primarily upright but can root at the lower nodes. It branches freely from the base stems, which are square in cross section and green or purple in color. Leaves are rounded, coarsely toothed, hairy, and deeply veined. They are opposite on petioles in the lower portion of the stem. The upper leaves are sessile or clasping the stem. Flowers are in whirls in the axils of the upper leaves. Petals are purple and fused into a two-lipped tube.

Knawel
[*Scleranthus annuus* L.]

Knawel is a winter annual which when it first germinates may go Large hop clover Carolina geranium Knawel unnoticed because of its grass-like features. It is a freely branched plant with spreading stems. Leaves, clasping the stem, are opposite, linear, less than 1 mm wide, and sharp-pointed. The very inconspicuous flowers are clustered in the leaf axils. They are small, green, lacking petals, and somewhat spiny to the touch.

Parsley-piert
[*Alchemilla microcarpa*
Boiss. and Rent.]

Parsley-piert is a freely branched winter annual about 1 to 3 inches tall. Leaves are alternate and palmately dissected. They may also be described as three-lobed with each lobe again three- to four-lobed. They may be petiolate or sessile with a cone-shaped toothed portion (stipules) at the base that encircles the stem. The inconspicuous flowers are borne in axillary clusters and surrounded by the stipules.

Corn Speedwell
[*Veronica arvensis* L.]

Corn speedwell is a small, weak, low-growing winter annual that thrives in thin open turf and often appears in solid stands. The lower leaves of corn speedwell are rounded and toothed, while the upper leaves are smaller and more pointed. The entire plant is covered with soft, fine hairs. The flowers are small, bright blue with white throats, and nearly stalkless. The seedpods are heart-shaped. Purslane speedwell [*V. peregrina* L.], which is a much-branched, somewhat succulent winter annual with linear leaves and white flowers, also occurs in the state.

Spurweed
[*Soliva pterosperma* (Jussieu) Lessing.]

Spurweed is a low-growing, freely branched winter annual, which usually does not root at the nodes. Leaves are opposite and twice pinnately dissected. The flowering heads are borne sessile in the forks of branches. Flowers are small (to ¼ inch), broad, and inconspicuous. The seeds have sharp spines, hence the common name. Infestations are increasing in North Carolina, particularly in the southern Coastal Plains and Piedmont.

Johnnyjumpup Violet

[*Viola rafinesquii* Greene]

Johnnyjumpup violet is a winter annual with erect freely branched stems growing ½ to 5 inches tall. The leaves are borne alternate on the stem with prominent dissected stipules. Flowers are borne on prominent stalks from the upper nodes. Flower petals may be white with blue veins or entirely bluish to bluish-violet. They appear like a miniature common violet flower.

SUMMER ANNUAL BROADLEAF WEEDS

Summer annual broadleaf weeds emerge in the spring or early summer, grow during the summer, and produce seed in mid- to late summer. Mid-summer rains frequently encourage germination.

Prostrate spurge may flower within three to four weeks after emerging in mid-summer. Prostrate spurge, prostrate knotweed, and lespedeza can survive close mowing because of their prostrate growth habits.

WEED MANAGEMENT PRACTICES

Maintain a dense, actively growing turf through proper mowing, fertilizing, and watering practices. Mow at the proper height for your selected adapted turfgrass. For example, mowing a bluegrass/tall fescue mixture at less than 2 inches will encourage the encroachment of summer annual broadleaf weeds as well as grassy weeds. Some summer annual weeds, like prostrate spurge, can be effectively controlled with preemergence herbicides, which also control crabgrass before the seeds germinate. Prostrate knotweed competes most effectively in compacted soils.

Coring and traffic control reduce compaction and encourage desirable turfgrass competition. Spray infested areas with a selective broadleaf postemergence herbicide when the weed is young, usually three- to four-leaf stage. It is best to control summer annual broadleaf weeds in late

spring or early summer when they are in the young development stage. They are easier to control at that time and both warm-season and cool-season turfgrasses have a greater chance to recover the areas previously occupied by weeds.

Prostrate Knotweed
[*Polygonum aviculare* L.]

Prostrate knotweed is a low-growing annual. It is a very competitive weed in infertile and compacted soils and often invades turfgrasses along driveways, sidewalks, and beaten paths cross lawns. The tough, wiry, slender stems radiate from a central taproot and produce a tough mat-like growth. Leaves are dull, bluegreen, oblong in shape, smooth, and alternate with a membrane at the base sheathing the stem. The tiny white flowers are inconspicuous and are borne at the nodes. This weed germinates with the first warm temperatures in the spring. Newly emerging seedlings are often mistaken for grasses in very early stages of development.

Lespedeza
[*Lespedeza striata* (Thumb.) H. and A.]

Lespedeza is a dark green, wiry annual with trifoliate leaves. Several wide-spreading prostrate branches come from the slender taproot. It grows close to the ground and seldom is cut by a mower. It is a very common summer weed, choking out thin turf. Hairs grow downward on the stem. Leaves are composed of three leaflets. 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.

Prostrate Spurge
[*Euphorbia supina* Raf.]

Prostrate spurge is a summer annual with a taproot. It branches freely from the base. The reddish or green prostrate stems form a mat-like growth, which often chokes out desirable turfgrasses. 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. The fruit, a three-lobed capsule, develops rapidly.

PERENNIAL BROADLEAF WEEDS

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. Dandelion and dock have fleshy taproots. Ground ivy and white clover have creeping stems which root at the nodes. India mock-strawberry has stolons and wild garlic has underground bulbs. These perennial broadleaf turfgrass weeds may be considered as cool-season perennials. Some actively grow during the summer in the western part of the state (for example, dandelion and plantains) but they are less active in the east. They thrive in weak, thin turf; golf fairways and roughs; home lawns; playfields; and industrial grounds. White clover may be found under close mowing conditions on golf greens.

WEED MANAGEMENT PRACTICES

Proper turf maintenance is also the key to perennial broadleaf weed control. Maintaining soil phosphorus at medium levels and nitrogen at the proper level for the desired turfgrass reduces the competitive ability of white clover in turf. Development of ground ivy and India mock strawberry is encouraged by shady, moist areas. Therefore, improving surface drainage, aerating when needed, and watering infrequently will help reduce encroachment of these two weeds.

Spray broadleaf weeds with an appropriate postemergence herbicide in March or April depending upon the location within the state. Select the herbicide according to the weeds to be controlled and the tolerance of the turfgrass. For example, bentgrass and hybrid bermudagrasses are less tolerant to 2,4-D than bluegrass, fescue, and common bermudagrass. A product containing two or three broadleaf herbicides may need to be selected if several different weeds are present. Some perennial broadleaf weeds may require a second application four to six weeks after the first. Dandelion and white clover may also be effectively controlled with fall applications. Centipedegrass is sensitive to 2,4-D products. When spraying centipedegrass, reduce the recommended rate for other grasses in half and repeat in four weeks for increased safety.

Blackseed Plantain
[*Plantago rugelli* Dene.]

Blackseed plantain is a fibrousrooted perennial with smooth lower leaves that are oval to elliptical in shape and purplish at the base of the leaf stalk. Leaf blades are often 1 to 3 inches wide and 3 to 6 inches long. Leaf margins may be wavy with five prominent veins. The rosette of leaves may lie close to the ground, crowding out desirable grasses. Flowers are arranged along more than half of the stem.

Buckhorn Plantain
[*Plantago lanceolata* L.]

Buckhorn plantain is a very common fibrous-rooted perennial weed found in poorly managed turfgrasses. The leaves are basal, long, narrow, and pointed with several prominent parallel veins. Flowers are arranged in a dense terminal spike on a long, hairy, leafless stem. As it blooms, the stamens are exerted from the spike.

Broadleaf Dock
[*Rumex obtusifolius* L.]

Broadleaf dock is a taprooted perennial similar to curly dock, but the leaves are broader and may be somewhat oval in outline with a heart-shaped base. They are often 3 to 4 inches wide and 6 to 10 inches long and produced mostly basal. Flowers are produced in clusters at the ends of the stems. They are green, turning reddish-brown at maturity. The three sepals covering the shiny brown seed have toothed edges.

Curly Dock
[*Rumex crispus* L.]

Curly dock is a perennial with a thick taproot. Leaves grow mostly at the base of the plant and are lance-shaped with wavy or curly margins. Leaf blades are 6 to 8 inches long and 1 to 2 inches wide. The green leaves may be tinged with reddish purple. Curly dock seldom produces seed in maintained turf. When the plants grow unchecked, small greenish flowers are produced in clusters at the top of the main stems. Flowers become reddish-brown at maturity. The shiny, reddish-brown triangular seed is surrounded by three sepals.

Dichondra
[*Dichondra repens* Michx.]

Dichondra is a perennial, spreading by slender creeping stems that root at the nodes. It forms mats not over 1½ to 3 inches tall. The kidney-shaped to nearly circular leaves grow alternate to each other, sometimes appearing whirled on the stems. The white to greenish small flowers are borne in clusters in the leaf axils below the level of the leaf. Dichondra is cultivated as a ground cover in some states.

Dandelion
[*Taraxacum officinale* Wiggers]

Dandelion is a hardy perennial with a thick, fleshy taproot and no stem. Leaves grow in a rosette from the crown. They are long, narrow, irregularly lobed, and lance shaped. The lobed tips are often opposite each other and pointing toward the crown. Leaves are often purple at the base and emit a milky latex when broken. The deep golden yellow flowers are borne in heads on long hollow stalks. Blossoms soon mature into spherical clusters of whitish fruits, like white puffballs, composed of parachute-like seeds. Seeds are carried by the wind.

Florida Betony
[*Stachys floridana* Shuttlew.]

Florida betony is a hard-to-control perennial weed that emerges in the fall and becomes a problem in late winter and spring. It is easily recognized by the very characteristic white tuber that resembles a rattlesnake rattle. This weed also has square stems and produces white to pink flowers in the spring. North Carolina is the northern border of its range. It is found in the southern United States west to Texas.

Ground Ivy
[*Glechoma hederacea* L.]

Ground ivy is a perennial with creeping stems, which root at the node. It forms dense patches and thrives in the sun and shade. The leaves are round, scalloped along the margin, heavily veined and rough on the upper surface. They are borne opposite each other on square-shaped stems. Funnel-shaped blue to violet flowers are found in clusters in leaf axils and occur in the spring.

India Mockstrawberry
***Duchesnia indica* (Andr.) Focke]**

India mockstrawberry is a perennial, spreading by hairy stolons (runners). 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.

Mosses
[*Bryum, Ceratodon, Hypnum,* or *Polytrichum* spp.]

Mosses are branched, thread-like primitive forms of plant life that form a thick green mat at the soil surface. They are very competitive in cool, moist, shaded locations such as the north side of buildings and wooded areas. Moss development is favored by low fertility, poorly drained soils, high soil acidity, poor watering practices, soil compaction, or a combination of these factors that adds up to thin, weak turf. Spiking, coring, or raking may be necessary for removal before chemical treatment.

Virginia Buttonweed
[*Diodia virginiana* L.]

Virginia buttonweed is a herbacious perennial with prostrate or spreading branches. The stems are longitudinally ridged, especially below the nodes, with hairs along the ridges. The leaves are opposite without petioles and rough along the margins. The leaves are slightly thickened, green on the upper surface and light green on the lower surface with both surfaces smooth and slightly folded. The leaves of Virginia buttonweed often take on a mottled-yellow mosaic look. The white flowers sometimes have pink streaks in the center and are borne in the leaf axil. Petals are united into a tube. The fruit, bearing four membranous sepals at the tip, is produced in leaf axils.

White Clover
[*Trifolium repens* L.]

White clover is a perennial with creeping stems rooting at some nodes. Leaves have three leaflets with a long erect petiole that is Virginia buttonweed surrounded at the base by a membranous sheath. 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 ½ to1½ inches in diameter. The petals are white or occasionally tinged with pink.

Wild Garlic
[*Allium vineale* L.]

Wild garlic is a perennial plant with an odor of garlic, which develops from a basal bulb covered by membranous coat. At maturity the bulb is covered with small yellowish bulbs, flattened on one side, which readily split apart. Leaves are hollow and round. The greenish pink to purplish flowers are borne in clusters at the stem tip and are often mixed among small greenish aerial bulblets.

Yellow Woodsorrel, Common
[*Oxalis dillenii* Jacq.]

Common yellow woodsorrel is a herbaceous perennial supported by a shallow taproot. It sometimes has very short stolons. 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 ½ to 1 inch long. The supporting stalk bends just below the capsule. It blooms primarily during March to April.

Diseases

Many diseases occur on the different turfgrasses that are used throughout North Carolina. Most of the diseases are caused by fungi and nematodes. Some problems that resemble diseases are caused by environmental or management factors such as wilt, cold, heat, high soluble salts, soil compaction, or chemical damage. Careful identification of the cause of a problem is important for the selection of proper control methods. Information is presented here on turf management practices to help reduce damage from the most important diseases on turfgrasses. Chemical recommendations are given in other publications such as *Pest Control for Professional Turf Managers* and the *North Carolina Agricultural Chemicals Manual*.

Susceptible plants, a favorable environment, and a pathogen are required for a disease to develop. 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. Nematodes cause the most damage when plants are grown under low water and limited nutrient conditions. 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. The selection of resistant plants can also be used to limit disease problems. Some cultivars are more susceptible to diseases than others. 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 and nematicides 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 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.

TURFGRASS DISEASES

Brown Patch

Cause: *Rhizoctonia* species

Hosts: Bentgrass, bluegrasses, ryegrasses, and tall fescue

Symptoms: Brown patches up to 3 feet in diameter develop with dead leaves remaining upright on closely mowed turf (golf greens) and matted down on higher cut turf. Leaves first take on a dark color, then wilt and turn brown. Grayish mycelium and freshly wilted grass may sometimes be observed in the early morning at the margins of rapidly developing patches when humidity and temperatures are high. This symptom, referred to as a "," is rarely observed on high-cut turf and usually disappears on low-cut turf as the grass dies and the humidity drops.

Symptoms on high-cut turf may resemble a ring with centrally located tufts of healthy grass observed within the patch. Strains of *Rhizoctonia solani* have been associated with this disease in North Carolina. Another brown patch-like disease, called yellow patch, develops on bentgrass greens during the cold-wet weather of the winter. The symptoms are yellow patches or rings ranging in size from 6 inches to 2 feet in diameter. Yellow patch is caused by *Rhizoctonia cerealis.* Brown patch has also been observed on tall fescue and bentgrass in hot weather from which *Rhizoctonia zeae* has been isolated.

Factors affecting disease development: Brown patch usually occurs in hot (above 85°F), humid weather 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. Poor soil drainage, lack of air movement, cloudy weather, dew, over-watering, and watering in late afternoon favor prolonged leaf wetness and increased disease severity. The application of high rates of nitrogen or lack of adequate levels of phosphorus and potassium, especially when conditions are favorable for brown patch development, have been shown to

contribute to turf injury from this disease. Excessive thatch, mowing when wet, and leaf fraying by dull mower blades have also been shown to enhance disease severity.

Control: Avoid the application of excessive rates of nitrogen when conditions favor disease development. In general, cool-season grasses should not receive more than one pound of nitrogen per 1,000 square feet at any one time. Use very low rates or avoid applying nitrogen in late spring or summer to cool-season grasses. Insure adequate amounts of potassium and phosphorus by applying these nutrients based on soil test results. Reduce prolonged leaf wetness by watering infrequently to a depth of 6 to 8 inches and at a time when the foliage is likely to dry quickly. Avoid watering in late afternoon and evening and allow for better air movement by removing

unwanted vegetation and relocating landscape plantings. Removal of morning dew reduces prolonged leaf wetness and exudates that favor disease development. This can be accomplished by dragging a hose, running the irrigation system for a short time, or by whipping the greens with bamboo or fiberglass pole. Good surface and soil drainage will help to reduce the incidence of this disease on cool and warm-season grasses. Make sure mower blades are sharp to reduce the amount of wounded turf through which the fungus can enter the plant. Avoid mowing grasses when wet and do not mow too low so that plants will be better able to ward off or recover from the disease. Golf greens should be regularly cultivated and top-dressed to reduce thatch buildup. Applications of effective fungicides when the first symptoms appear will give good control of

brown patch on cool-season grasses. A preventive fungicide program should be considered on bentgrass and ryegrass overseeded greens when conditions are favorable for disease development.

Dollar Spot

Cause: *Sclerotinia homoeocarpa*

Hosts: All turfgrass species ISEASES

Symptoms: Dollar spot appears as small, circular spots on low-cut turf such as golf greens. The grass in the spots may be killed to the soil surface if the disease continues to develop. These spots may merge in time resulting in large blighted areas. High-cut turf usually exhibits larger patches of bleached grass rather than individual spots. Individual blades remain upright and are characterized by having white or light tan lesions with reddish-brown margins. Leaves are usually girdled by these lesions so that the upper part of the leaves dies slowly on taller cut turf. Short, fuzzy white mycelium is often observed on the lesions in the morning when dew is present. The mycelium may be confused with the fluffy white or gray mycelium associated with Pythium blight. Spots in sod-forming grasses, such as bentgrass and bermudagrass, usually disappear once the disease is controlled; however, spots in bunch-type grasses such as ryegrass often remain because of their inability to fill in those areas that are damaged.

Factors affecting disease development: 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. Nutritionally deficient turf and plants growing in dry soils with high moisture levels around the leaves from dew or frequent irrigation are more

prone to dollar spot. The disease often develops earlier in the spring where it was not adequately controlled the previous fall. Leaf clippings and traffic (foot and vehicular) can also be a means of spread. Certain cultivars are very susceptible to dollar spot while others are fairly tolerant.

Control: Use of resistant cultivars is one of the best means of prevention. Base turfgrass selection on regional cultivar trials and University recommendations. Plant blends and mixtures of cool-season grasses whenever possible. Adequate nitrogen fertilization will help prevent or help plants recover from dollar spot. Use soil test results to apply the recommended amounts of phosphorus, potassium, and lime and other nutrients. Follow University recommendations concerning nitrogen rates and timing. Reduce prolonged leaf wetness and prevent dry soils by watering deeply but infrequently. Avoid late afternoon and evening waterings and remove morning dews by irrigating lightly in the early morning. (Dragging a hose over the area or using a whipping pole on golf greens may spread the disease.) 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. Remove excess thatch by power raking to reduce the potential for reinfection. Golf greens should be regularly cored and topdressed to reduce thatch buildup. 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.

Fairy Ring

Cause: Many basidiomycete-type fungi, which often produce mushrooms and puffballs in association with fairy rings

Hosts: All turfgrasses

Symptoms: Fairy rings may appear as small to very large arcs or rings consisting of very green grass, dead grass, mushrooms, puffballs, or a combination of these symptoms. The soil beneath the rings may become very dry and difficult to wet during the summer and fall. 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. Rings vary in size from 1 to 100 feet in diameter. Some fairy rings continue to enlarge for many years with an increase in diameter of 1 to 2 feet per year. Arcs or irregular circles are usually formed when fairy rings come together.

Factors affecting disease development: Fungi that cause fairy rings are common inhabitants of forested areas. These fungi begin growing on a source of organic matter such as an old stump in the soil or excess thatch in turf. Fairy rings usually cause more damage on drought-stricken, nutrient-deficient turf. Green rings are produced as a result of fungi decomposing organic matter and releasing nitrogen. The soil may become hydrophobic (water repellent) from the large amount of mycelium in the soil and is often very difficult to rewet. The grass may be weakened or killed by high concentrations of chemicals released by the fungi, root invasion by the fungi, or environmental stress such as drought.

Control: Removal of large sources of organic matter, such as stumps and waste lumber, before areas are planted, will help prevent disease development. Landscape contractors should remove these sources around new construction sites before seeding or sodding. Power rake or vertical mow to remove thatch when it exceeds ½ inch. Golf course superintendents should regularly core and topdress golf greens to prevent thatch buildup. Remove soil cores or in some manner open the soil within the ring to allow better nutrient and water penetration. Coring, spiking, use of wetting agents, and forcing water into the dry soil have provided some relief to this disease.

Infected areas should be hand watered to prevent overwatering of the entire area, which may prove harmful to the uninfected turf. Fertilize to meet the nutritional needs of the turf or lawn.

Regularly submit a soil sample for analysis and apply recommended amounts of phosphorus, potassium, and lime. Follow University recommendations concerning nitrogen rates and timing. 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. More drastic methods of control involve soil fumigation, soil removal, or turf renovation by rototilling and mixing the soil and replanting. Some fungicides drenched into the soil may control fairy rings.

Microdochium Patch
(Pink Snow Mold)

Cause: *Microdochium nivale*

Hosts: Bentgrass, bluegrass, fescue, and ryegrass

Symptoms: 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.

Factors affecting disease development: 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. 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.

Control: 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. 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.

Gray Leaf Spot

Cause: *Pyricularia grisea*

Hosts: St. Augustinegrass, ryegrass, and tall fescue

Symptoms: 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.

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

Helminthosporium Diseases

Cause: *Helminthosporium* species (now known as *Bipolaris, Drechslera,* and *Exserohilum* species).

Hosts: Bentgrass, bluegrass, fescues, ryegrasses, and bermudagrass

Symptoms: These fungi can cause leaf, crown, and root diseases. The leaf spot diseases are usually characterized by dark circular or oval shaped lesions in the early stages of development. Some lesions such as those found on Kentucky bluegrass may become tan colored and possess a dark margin. The lesions may enlarge and girdle the leaves resulting in a light tan or brown turf. Many of the diseases infect the root and crown and cause a gradual thinning or "" during stress periods. The melting out phase is characterized by dark lesions that occur on the sheaths of stunted, spindly shoots. 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.

Factors affecting disease development: 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 and are spread to leaves by wind, rain, irrigation, equipment, and foot traffic. The fungi may spread to the crowns and roots and cause plants to decline during periods of drought stress. Lush, succulent turf due to excessive nitrogen, wet conditions in the spring and fall, drought stress, and continual mowing at close heights are 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.

Control: 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. Cultivar selection should be based on regional trials and University recommendations. 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. 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.

Large Patch

Cause: *Rhizoctonia solani*

Hosts: bermudagrass, centipedegrass, St. Augustinegrass, zoysiagrass

Symptoms: Large patch develops on warm-season grasses in the fall and spring, as these grasses are going into or coming out of winter dormancy. 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 edge 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.

Factors affecting disease development: 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. 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. 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.

Control: 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. 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.

Nematodes

Cause: Several different nematode species, primarily sting (*Belonolaimus* species), stubby-root *(Trichodorus* species) and lance (*Hoplolaimus* species)

Hosts: All turfgrasses

Symptoms: Nematodes are microscopic, eel-like worms that cannot be observed without the aid of a microscope. 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.

Factors affecting disease development: Nematodes are most damaging in light, sandy soils which are low in nutrients and water-holding capacity. Good fertilization and irrigation practices will often overcome the effects of some types of nematodes. Nematodes are fairly immobile in soil and spread is frequently due to movement of soil and plants 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. Nematode levels are usually lowest in the spring and increase to the highest levels in the fall. These changes are related to soil temperatures in the upper South. Early fall is a good time to have soil samples assayed for nematodes.

Control: Make sure that the problem is due to nematode injury by taking a representative soil sample from the affected area and submitting it to a laboratory for analysis. North Carolina residents should contact their local Cooperative Extension Service agent for nematode assay boxes and information sheets. Samples, consisting of 12 to 15 soil cores approximately 4 inches in length, should be taken from the edge of the affected area. The sample must not be allowed to dry out or be exposed to extreme heat, otherwise nematodes will be killed and an

accurate count cannot be made. Soil samples should also be submitted to determine if the nutritional needs of the turf are being met. Selection of the most tolerant types of grasses and good management practices will help overcome 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. Nematicides may be needed on highly maintained areas such as tees and greens when the sting nematode is present. Labeled chemicals are very toxic to humans and animals so label directions should be followed if they are used.

Powdery Mildew

Cause: *Erysiphe graminis*

Hosts: Bluegrass

Symptoms: 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.

Factors affecting disease development: 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. Unlike many other fungi, free water on leaves is not required for infection by *Erysiphe* species. The disease is usually more severe in shaded areas with poor air circulation during long periods of dry weather.

Control: 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 waterings 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. Several fungicides can be used to control this disease.

Pythium Blight

Cause: *Pythium* species

Hosts: Bentgrass, ryegrass, and tall fescue

Symptoms: Pythium blight first appears as small, sunken circular patches from 1 to 12 inches in diameter during warm to hot, 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- oaked 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.

Factors affecting disease development: Pythium blight becomes very active when relative humidity is high and day and night temperatures exceed 85°F and 68°F, respectively. 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.

Control: Reduce prolonged leaf wetness by watering deeply but infrequently to a depth of 6 to 8 inches. Avoid overwatering, late afternoon and evening watering, and light, frequent irrigations. Insure good surface and soil drainage by using well-drained soil mixes on golf greens and by aerifying or coring to reduce compaction and improve water infiltration. 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 and prevent the spread of this disease by making sure that mowing equipment is washed before going to a noninfected area. Golf course superintendents should encourage members to clean their shoes between each round. 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. As with mature turf, avoid overwatering and make every effort to reduce the time in which the young seedlings remain wet between waterings. 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.

Red Thread

Cause: *Laetisaria fuciformis*

Hosts: Bentgrass, bluegrass, fescue, and ryegrass

Symptoms: 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 "") that radiate from the tips of dead leaves under high humidity. Red thread occurs most often during the spring but can occur throughout the summer at high elevations.

Factors affecting disease development: Red thread develops during prolonged periods of cool weather when leaves are wet from dew, fog, or frequent, light irrigations. It develops best

when the grass is growing slowly from inadequate fertilization, lack of water, cool weather, or other pest or environmental stresses.

Control: Fertilize to meet the nutritional needs of the turf. Submit a soil sample for analysis on a regular basis and apply recommended amounts of phosphorus, potassium, and lime. Apply nitrogen based on University recommendations to prevent weak, thin turf; 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. Some fungicides will give good control of red thread.

Rust

Cause: *Puccinia* species

Hosts: Bluegrass, ryegrass, tall fescue, and zoysiagrass

Symptoms: 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.

Factors affecting disease development: 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. Free water on the leaves for certain periods of time is necessary for the spores to germinate and for the disease to develop rapidly. Low light intensity, inadequate fertilization, drought stress, and infrequent mowing favor this disease.

Control: Planting rust resistant turfgrass cultivars whenever possible will reduce potential injury from this disease. Cultivar selection should be based on regional trials and University recommendations. 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. Mow turf on a continual basis removing no more than 30 to 40 percent of the foliage in one mowing. Collect and dispose of clippings taken from infected areas to avoid spread of this disease. Wash equipment before entering noninfected areas. Fertilize to meet the nutritional needs of the turf. Submit a soil sample for analysis on a regular basis and apply recommended amounts of phosphorus, potassium, and lime. Apply nitrogen based on University recommendations. 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. Several fungicides can be used to control rust diseases.

Slime Mold

Cause: *Mucilago, Physarum*, and *Fuligo* species

Hosts: All turfgrasses

Symptoms: Many small purple, white, gray, yellow, or orange fruiting bodies of these fungi may suddenly appear on leaves of turfgrasses in small patches. Slime molds usually appear during or after extended periods of warm wet weather. 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.

Factors affecting disease development: Spores survive in the soil and on thatch. The spores germinate and develop into a colorless, slimy mass that grows over the soil and nearby plant parts during wet weather. The reproductive structures are the small colored bodies that develop on the leaves during warm wet weather.

Control: The slime molds may be removed by brushing, mowing, or washing the turf. Fungicides are not needed, but some can be used to control these fungi if the problem is too unsightly.

Southern Blight

Cause: *Sclerotium rolfsii*

Hosts:Bentgrass, bluegrass, and ryegrass

Symptoms: 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.

Factors affecting disease development: 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: 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. Follow University recommendations concerning timing and rates for nitrogen application. Several contact and systemic fungicides have given good control even after symptoms have been observed.

Spring Dead Spot

Cause: *Ophiosphaerella* species

Hosts: Bermudagrass

Symptoms: Dead spots or patches first appear in 3- to 5-year-old bermudagrass in the spring as bermudagrass resumes growth from winter dormancy. The patches appear in many of the same places and expand in size year after year. 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. 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 preemergent herbicides will slow the growth of stolons over the spots.

Factors affecting disease development: 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.

Control: 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. Several fungicides have given good control of spring dead spot when applied at high rates in the fall (August 15 to October 15) 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.

Take-all patch

Cause: *Gaeumannomyces graminis var. avenae*

Hosts: Bentgrass

Symptoms: 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.

Factors affecting disease development: 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.

Control: 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. 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.

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