

# BEST MANAGEMENT PRACTICES FOR LAWN AND LANDSCAPE TURF

version 1.51

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The mission of the UMass Extension Turf Program is to develop, research, gather, and share knowledge on safe, efficient, economically viable and environmentally sound turf management with emphasis on natural resource protection.

The information in this guide is not presented as recommendations, but rather as research-based and expertly audited knowledge intended to help practitioners make informed decisions. The content authors make no guarantees and assume no liability as to the efficacy of outlined practices or listed materials. The user of this information assumes all risks and liability for personal injury and property damage.

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# INTRODUCTION

## LAWN AND LANDSCAPE TURF: A KEY RESOURCE

Residential and commercial lawns and utility-type turf comprise a significant portion of the Massachusetts landscape. These lawns may be at private residences, at business establishments, in industrial developments, on municipal properties, in parks, on public or private school grounds, and along roadsides and other utility areas. Lawns and similar turf areas are key resources, as they contribute to open space, provide recreation, add value to properties, and help to protect the environment.

Properly maintained turf provides many functional, recreational, and ornamental benefits, which are summarized below.

**Table 1. Benefits of turf.**

Functional		Recreational	Ornamental
<ul style="list-style-type: none"> <li>▪ Dust and mud control</li> <li>▪ Entrapment of pollutants</li> <li>▪ Environmental protection</li> <li>▪ Fire prevention</li> <li>▪ Glare reduction</li> <li>▪ Ground water recharge</li> <li>▪ Slope stabilization</li> </ul>	<ul style="list-style-type: none"> <li>▪ Heat abatement</li> <li>▪ Noise abatement</li> <li>▪ Security-visibility</li> <li>▪ Soil loss and erosion control</li> <li>▪ Protection of underground utility services</li> <li>▪ Greenhouse gas reduction</li> <li>▪ Storm water abatement</li> </ul>	<ul style="list-style-type: none"> <li>▪ Safe playing surfaces</li> <li>▪ Low cost surfaces</li> <li>▪ Mental health</li> <li>▪ Physical health</li> <li>▪ Entertainment</li> </ul>	<ul style="list-style-type: none"> <li>▪ Beauty</li> <li>▪ Increased property value</li> <li>▪ Community pride</li> <li>▪ Complements the landscape</li> <li>▪ Mental health</li> </ul>

Adapted from J. B. Beard and R. L. Green, 1994, from The Journal of Environmental Quality, *The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans*.

Improperly or poorly maintained lawns are less functional in terms of aesthetics and recreation, may result in inefficient use of valuable natural resources such as water, and are more likely to be sources of environmental contamination.

**Best Management Practices (BMPs)** are intended to maximize the benefits of lawn areas and to minimize the potential for environmental impact that can happen as a result of inefficient, incorrect or irresponsible management practices.

# BEST MANAGEMENT PRACTICES: AN OVERVIEW

**Best Management Practices (BMPs)** for lawn and landscape turf are economically feasible methods that conserve water and other natural resources, protect environmental quality and contribute to sustainability.

The **BMPs** detailed in this document are agronomically sound, environmentally sensible strategies and techniques designed with the following objectives:

- **to protect the environment**
- **to use resources in the most efficient manner possible**
- **to protect human health**
- **to enhance the positive benefits of turf in varied landscapes and uses**
- **to produce a functional turf**
- **to protect the value of properties**
- **to enhance the economic viability of Massachusetts businesses and communities**

The **BMPs** in this document are based on the scientific principles and practices of integrated pest management (IPM). IPM is a systems approach that should form the foundation of any type of sound turf management program. This holds true whether the materials being used are organic, organic-based or synthetic. The components of IPM for lawn and landscape turf are detailed below and are described in more detail in later pertinent sections of this document.

**What is IPM?** - Integrated Pest Management (IPM) is a systematic approach to problem solving and decision making in turf management. In practicing IPM, the turf manager utilizes information about turf, pests, and environmental conditions in combination with proper cultural practices. Pest populations and possible impacts are monitored in accordance with a pre-determined management plan. Should monitoring indicate that action is justified, appropriate pest control measures are taken to prevent or control unacceptable turf damage. A sound IPM program has the potential to reduce reliance on pesticides because applications are made only when all other options to maintain the quality and integrity of the turf have been exhausted.

The key components of an IPM system for turf can be tailored to fit most management situations. The steps in developing a complete IPM program are as follows:

1. **Assess site conditions and history**
2. **Determine client or customer expectations**
3. **Determine pest action levels**
4. **Establish a monitoring (scouting) program**
5. **Identify the pest/problem**
6. **Implement a management decision**
7. **Keep accurate records and evaluate program**
8. **Communicate**

These **BMPs** are intended for use in the management of lawn and landscape turf. While many of the practices delineated can be applied to the management of sports turf and other more intensively used turf, it is not the intent of this document to provide the more specialized **BMPs** that such intensive management systems require.


These **BMPs** are designed to be used in a wide range of lawn and landscape management situations. Not every **BMP** will apply to every site. Activities and practices may vary depending on management objectives and site parameters. In addition, there may be a specific practice or practices appropriate for an unusual site that does not appear in this document.

When instituting a management program based on **BMPs**, the turf manager must first determine the desired functional quality of the lawn and the management level and resources necessary to achieve it. Various factors will need to be considered including site parameters, level and intent of use, potential for pest infestation, pest action level, and environmental sensitivity of the site.

**BMPs** for maintenance of lawn and landscape turf areas are most effectively implemented by an educated and experienced turf manager, but can also serve as guidelines for less experienced turf managers and others caring for lawn and landscape turf.

## USING THIS DOCUMENT

The following describes the manner in which this document is set up:

 <b>OBJECTIVE</b>	<b>Each section of this document contains management objectives that lead to overall goals: safety, protection of water and other natural resources; enhancement of environmental quality, sustainability, and economic feasibility.</b>
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**Following each objective are the BMPs that support and contribute to that particular objective.**

- Additional supporting information and detail appears in the bulleted text below each BMP.

## SECTION 1

### DEVELOPMENT AND MAINTENANCE OF A KNOWLEDGE BASE

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 <b>OBJECTIVE</b>	<b>Maintain organized references on agronomics, management materials and pests, and provide for easy access to information as needed.</b>
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#### **Develop and maintain professional turf management competency.**

- This may include attending degree or certificate programs, workshops, conferences, field days, seminars and/or webinars, and in-house and on-the-job training

#### **Learn about pest identification and biology to effectively implement pest management strategies.**

- If an insect, disease, or weed population affects a lawn area, the turf manager must be knowledgeable about the life cycle of the problem pest.
- For example, when is damage most likely to occur? What is the most susceptible stage for control? How can cultural practices be targeted to reduce pest populations?

#### **Maintain an organized library of turf management reference materials.**

- The development of a library of reference materials will provide easy access to information as needed.
- Many excellent references are available. Consult Appendix E on page 127 of this document for a list of suggested resources and references.

#### **Reference materials and other reliable information sources could include:**

- reference textbooks (see appendix)
- trade journals
- pest management guides
- university and associated newsletters and e-newsletters
- electronic media, websites



## **Create and maintain current files for key pests (weeds, diseases, and insects) as well as abiotic stresses.**

- Hard copy or electronic files may consist of articles, fact sheets, images, web sites, excerpts from larger publications, personal notes, etc.

### **Example information that might be included in each pest file:**

- life cycle
- environmental conditions and weather that favor pest activity
- symptoms
- best monitoring time
- best monitoring technique
- effective management tools and techniques: cultural, chemical, biological

## **Obtain and maintain appropriate licenses and professional certifications.**

- Individuals applying pesticides should be properly licensed and/or certified as required by law.
- Association memberships and professional certification programs (e.g. MCLP, MCH, CSFM) are useful avenues for professional development.

## **Identify and access a reliable source of weather information regularly.**

- Weather conditions and soil temperatures play a role in determining timing of cultural practices as well as pest activity and severity.

### **Types of critical data should include current, accurately predicted and archived information on:**

- most recent and forecast weather
- temperature
- precipitation
- relative humidity and dew points

## **Note and record specific weather or phenological information.**

- It is often useful to monitor and record soil temperatures at 1.0 inch weekly during key times of the season at locations representative of the range of different microclimates being managed.
- A record of dates of full bloom of key bio-indicator plants (i.e. *Forsythia*, dogwood, horsechestnut) can be important in tracking pest development.
- Major, extreme or unusual weather events and their effects on turf or implications for applications of fertilizer or pest management materials.

## SECTION 2

### SITE ASSESSMENT

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 <b>OBJECTIVE</b>	<b>Determine and record site conditions, including areas of environmental sensitivity, as well as current and past problems and potential for future problems.</b>
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**Conduct a detailed assessment of each site to be managed.**

- Accurate site specifications are indispensable for planning with relation to management practices, materials applications, and renovation or reconstruction.
- Problem areas that impact turf health directly affect the potential loss of turf quality and function and increase the likelihood of pest infestations.

**Points to consider in a thorough site assessment include:**

- map or photo record of property
- square footage of turf area(s) being managed
- drainage patterns
- as-built drawings/maps of drainage and irrigation systems
- determination of functional condition and adequacy of drainage and irrigation systems
- the age, condition, and species composition of the turf (including cultivars if known)
- the physical condition, texture, and variation of soils on the site
- a current soil pH and nutrient analysis
- the fertility history and a summary of the current fertility program
- a pest history and current or potential problems

**Identify and record permanent features of each site in relation to management of the turf.**

- Permanent features on or in close proximity to the site should be assessed from two perspectives:
  1. How turf function and quality might be impacted by these features.
  2. How these features might be impacted by turf management practices.

**The following are important items and structures that might be included:**

- trees, shrubs, gardens and other landscape plantings.
- driveways and walkways
- parking lots and roadways

- fencing
  - buildings
  - temporary structures
  - monuments or grave markers
  - playgrounds and/or daycare facilities
  - decorative ponds
  - significant abutters that have potential for impact
- Changes to this record should be made as they occur.

**Devote particular attention to the identification of areas of environmental sensitivity.**

- Similar to above, areas of environmental sensitivity on or in close proximity to the site should be assessed from two perspectives:
  1. How turf function and quality might be impacted by these areas.
  2. How these areas might be impacted by turf management practices.

**The following are key areas that should be included:**

- wetland protection resource areas
- wells on property
- wells in proximity to property
- Zone I & II areas
- surface water features
- high water table areas
- catch basins
- exposed bedrock
- other environmentally sensitive areas

**Determine and record agronomic problems in key locations and consider potential solutions.**

- The recognition of agronomic problems is the first step in developing a solution.

**Problems to note include but are not limited to the following:**

- inappropriate turfgrass species or cultivars
- poor fertility
- undesirable soil types
- excessive thatch
- excessive traffic stress
- compaction
- pet damage
- poor drainage
- shade
- localized dry spots
- poor air circulation

- southwest facing slopes
  - tree root influence
  - shallow soil or bedrock
  - areas prone to damage from snow removal or salt application
-

## SECTION 3

### DEVELOPMENT OF A MANAGEMENT PLAN

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 <b>OBJECTIVE</b>	<b>Determine the intended use and expected quality of the turf in making strategic and cultural management decisions.</b>
---	---

**Determine customer or client expectations to inform management objectives.**

- In general, the higher the level of quality desired, and the more intense the use of the turf, the higher the level of management needed to maintain a quality surface.
- Set realistic expectations based on communication between turf practitioner and customer or client.

**Expectations considerations include, but may not be limited to:**

- use and appearance of lawn
- acceptable level of pest infestation
- acceptable level of abiotic stress
- use of water and other resources
- use of synthetic, organic-based or organic management materials
- budget and other financial resources
- other site specific details



*High maintenance*



*Moderate maintenance*



*Minimal maintenance*

**OBJECTIVE****Determine and document action levels for various pests.****How much pest activity can be tolerated before action is necessary?**

- This question will help to determine the response threshold or action level.
- The action level is the point at which a pest population reaches a level capable of causing unacceptable damage to the turf.
- The higher the level of turf quality desired, the lower the action level and the more likely it is that a turf manager will need to make a pesticide application to manage a problem pest.

**Establish action levels for each key pest according to turf management objectives.**

- Action levels for various pests will vary from site to site and may even vary from area to area on a given site.
- Due to the many factors that play a role in determining action levels, setting 'across the board' levels is often not useful.
- Action levels may change during the growing season, in response to changes in management inputs, or in response to other pest or abiotic problems.
- Action levels may be affected by the number of monitoring events or visits. In many cases, the less often monitoring is done, the more likely it is that the action level will be lower.
- Ancillary information such as plant phenology and bio-indicators (stage and date of plant development) as well as growing degree days can also be considered.

The following factors will influence action levels and should be considered carefully:

- client or customer expectations
- management objectives
- turfgrass species and cultivars present
- turf use
- vigor and condition of turf
- time of year
- weather and environmental conditions

**OBJECTIVE****Develop and implement a site specific management plan.****Set strategies for the upcoming year with an annual management plan.**

- Formulate a yearly management plan based on site assessment information, client expectations and pest action levels as determined for the site.

**The following information at a minimum should be included:**

- management objectives and practices
- regulations that impact the particular site, and compliance factors for those regulations
- identification of agronomic problems, with a plan for addressing causes:
  - irrigation
  - drainage
  - excess wear and traffic
  - landscaping (trees and shrubs)
  - soil problems
- cultural practices:
  - construction, renovation, repair if needed
  - seeding/overseeding
  - irrigation
  - fertility management
  - mowing
  - aeration and topdressing
  - other practices specific to the site
- scouting timetable and procedures
  - identification of key pests in key locations at key times
  - training and assignment of scouting personnel
- pest management strategies
  - determination of pest action levels
  - scouting/monitoring plan
  - cultural management
  - biological management
  - pesticide management

**Monitor or scout for pests, potential pest problems and environmental stresses.**

- Managed sites should be checked on a routine basis for pest presence, pest population density, and pest damage.
- Other potential problems (i.e. heat stress, excessive thatch accumulation, etc) should also be noted and recorded.
- Consult the appropriate pest sections of this manual for information useful in monitoring disease, insect, and weed pests as well as problems caused by abiotic factors.
- Refer to the *Turf Pest Damage Monitoring Chart* on page 116 for approximations of when damage is most likely to occur.

**Keep a written record of monitoring findings with an intended course of action.**

- List or map locations where particular or key pests or problems first occurred during critical periods.
- List or map locations where particular environmental or other abiotic stresses first occurred during critical periods.
- Record action needed, and also action taken.

## **Record management activities.**

- Keep a detailed record of yearly growing conditions and management activities.

### **Suggested record items:**

- temperature
  - precipitation
  - humidity
  - pest problems
  - pest 'hot spots'
  - pesticide applications and results
  - timing, frequency and effectiveness of cultural practices
  - fertilizer and other materials applications
  - soil and tissue test results
  - soil pH
  - uncommon occurrences such as flood, prolonged ice cover, etc.
- Note management activities that differ from those outlined in the yearly management plan.
  - Determine if measures taken to manage a pest or alleviate a problem were truly effective in protecting and maintaining the quality and viability of the turf. These evaluations should be maintained as a key aspect of the written record.
  - Keep pesticide application records as required by law.
  - If applicable, customer program, invoicing and associated records should be kept on file.
  - Staff should be trained in Right to Know and other pertinent laws, and documentation should be retained in personnel files.
  - Training records for staff using or handling materials and doing field work should be retained.

## **Encourage and maintain communication between supervisors, crew and other staff.**

- Effective communication will promote success of management decisions and results.
- Train staff and crew in proper procedures.

## **Share the yearly management plan.**

- Share management plans with appropriate staff, clients, and/or end-users. Discuss as needed.
- Clients, and/or end-users who utilize turf subject to pesticide applications should receive notification and documentation as required by law.
- If requested by clients and/or end-users, provide advance notice of site visits and applications.
- Provide an information sheet, post-treatment instructions and documentation to clients and/or end-users as appropriate.



### **Evaluate the management plan as implemented.**

- All aspects of the management plan including pest management strategies should be evaluated each year and a written summary kept.
  - Management strategies that need to be adjusted or implemented during the coming year can be identified in the course of the annual evaluation.
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## SECTION 4

### TURFGRASS SELECTION

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 <b>OBJECTIVE</b>	<b>Select turfgrass species and cultivars that are well adapted to the environmental conditions and to the intended use and maintenance level of a particular site.</b>
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**Know the strengths and weaknesses of potential species and cultivars and select the right grasses for your site and management program.**

- Turfgrass species vary in terms of appearance, appropriate uses, cultural requirements, pest resistance and stress tolerance. Individual cultivars (or varieties) within species provide additional options for effectively matching grasses with growing conditions and desired performance.
- Selection of adapted turfgrass species and cultivars is fundamental to the success of any management program for turf, as poorly adapted species and cultivars are major causes of turf deterioration.
- Adapted grasses require less input in terms of water, fertilizer, and pesticides, and are far more likely to function as intended and exhibit favorable characteristics.

**Carefully consider the desired management level.**

- Consider the intended level of cultural intensity, the type of use, and the desired quality of the turf.
- Some grasses require a higher level of management input (water, fertility, mowing) to perform adequately than do some other grasses.
- High maintenance species are used where management receives a greater level of attention and effort. Common high maintenance areas include golf courses, athletic fields, parks, and some commercial or residential lawns.
- If a lower-input management scheme is desired, grasses are available that perform at an acceptable level with a relatively lesser degree of maintenance.
- Low maintenance turf species are typically adapted to situations with reduced inputs such as mowing, fertility, and irrigation. Areas appropriate for low maintenance species include roadsides, parking lots, industrial complexes, and some commercial or residential lawns.
- When specifying mixed stands, consider how they will trend if inputs are higher or lower.

### Identify potential growth-limiting factors.

- Determine the characteristics and the adaptations of the turfgrass species (growth habit, recuperative potential, leaf texture, shoot density, establishment rate, appropriate mowing height, etc).
- Abiotic growth limiting factors include conditions such as shade, traffic, infertility, acidic soil pH, flooding, shallow root zone, poor soil, low temperature, drought, close mowing, etc.
- Biotic growth limiting factors include pests such as insects, diseases and weeds.

**Table 2. Traffic tolerance and ideal soil characteristics for selected cool-season turfgrasses.**

Species	Wear	Compaction	Recovery	Soil Texture	Soil pH
<b>Kentucky bluegrass</b>	Fair	Good	Good	Well drained	6.0 to 7.0
<b>Perennial ryegrass</b>	Excellent	Excellent	Poor	Variable	6.0 to 7.0
<b>Fine Fescues (Chewings, creeping red, hard)</b>	Poor	Poor	Fair	Well drained	5.5 to 6.5
<b>Tall fescue</b>	Excellent	Fair	Poor	Variable	5.5 to 6.5

**Table 3. Environmental stress tolerances of selected cool-season grasses.**

Species	Cold	Heat	Drought	Salinity	Submersion
<b>Kentucky bluegrass</b>	Excellent	Fair	Good	Poor	Fair
<b>Perennial ryegrass</b>	Fair	Fair	Good	Fair	Fair
<b>Fine fescues (Chewings, creeping red, hard)</b>	Good	Fair	Good	Poor	Poor
<b>Tall fescue</b>	Fair	Good	Excellent	Good	Good

**Table 4. Cultural and maintenance requirements of selected cool-season turfgrasses.**

Species	Shade	Fertility *	Height of Cut	Mowing Frequency	Thatch Tendency
<b>Kentucky Bluegrass</b>	Poor	Medium-High	1.5 to 3.0 inch	Low-Medium	Medium
<b>Perennial Ryegrass</b>	Poor	Medium-High	1.5 to 3.0 inch	High	Low
<b>Fine fescues (Chewings, creeping red, hard)</b>	Excellent	Low	1.5 to 3.0 inch	Low	Medium
<b>Tall Fescue</b>	Fair	Medium-High	1.5 to 3.0 inch	Medium	Low

\* Fertility levels, in lbs. N per 1000 sq. ft.: medium-high = 3 to 5; low = 1 to 2.

### Take advantage of National Turfgrass Evaluation Program (NTEP) data.

- NTEP provides extensive, reliable information about the performance of turfgrass species and cultivars in specific regions of the country.
- NTEP does not make recommendations; therefore the data must be interpreted and used to make informed choices.
- The key parameter provided by NTEP is turfgrass quality (TQ). Other available descriptive data may include genetic color, density, leaf texture, winter injury, traffic tolerance, disease potential, etc.
- NTEP information is free and can be accessed on the web at <http://www.ntep.org>.

### Mix or blend species and cultivars whenever possible.

- Use of a single turfgrass species for establishment of a stand is rarely appropriate for lawns and similar turf areas, and is more common on some athletic fields and many golf courses.
- A turfgrass seed **mix** contains two or more different **species** of grasses.
- A turfgrass seed **blend** contains two or more **cultivars** of the same species of grass.
- Where appropriate, informed mixing and blending often results in a well-rounded turf that performs better than the sum of its parts.
- To incorporate diverse tolerances to pest and environmental stresses, mixes and/or blends are nearly always preferred to 'monostands' (a planting consisting of the same species and/or cultivar).

**Table 5. Recommended turfgrass mixtures (and uses) for Massachusetts.**

<b>Use</b>	<b>Species (% by weight)</b>	<b>Rate (lbs/1000 ft<sup>2</sup>)</b>
Lawns: sun, med. to high maintenance	65 to 75% Kentucky bluegrass* 10 to 20% perennial ryegrass* 15% fine fescue**	3 to 4
Lawns: sun, low maintenance	65% fine fescue* 10-20% perennial ryegrass* remainder Kentucky bluegrass	4 to 6
Lawns: shade	80 to 90% fine fescue* 10 to 20% perennial ryegrass*	4 to 6
Lawns: well drained	80% shade tolerant K. bluegrass* 20% perennial ryegrass*	3 to 4
<p><b>*Two to three improved cultivars recommended.</b>  <b>** One or more improved cultivars recommended.</b></p>		

**Exercise appropriate care when selecting and managing tall fescue.**

- Tall fescue is more readily adaptable to certain areas of New England, particularly the southern coastal areas.
- Some tall fescue cultivars can become coarse and unthrifty under conditions in which better adapted turfgrasses may grow.
- Careful cultivar selection is critical, not only for performance and quality, but also for disease tolerance.
- Tall fescue is particularly susceptible to brown patch and *Pythium* diseases. Consult UMass Extension’s *2010-2011 Professional Guide for IPM in Turf in Massachusetts*, or NTEP data for disease tolerance of specific cultivars.
- Many tall fescue cultivars tend to become clumpy in heavily trafficked areas, and may require frequent overseeding to maintain acceptable density.
- When it is desirable to use tall fescue in a lawn or in the landscape, use a mix of tall fescue in combination with Kentucky bluegrass or perennial ryegrass, with no less than 80% of the mix being tall fescue.

## SECTION 5

### ESTABLISHMENT, RENOVATION & REPAIR

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Turf establishment, by the simplest definition, is the planting of turfgrasses. There are several different types of planting events, ranging from new plantings (i.e. constructing a new turf area where one did not exist before), to renovation or re-construction of an existing turf area, to overseeding or repairs for established turf.

Mature, well-established turf is most functional as well as most tolerant of pests, use, cultural practices, and environmental stresses. Well-established turf is also more likely to exhibit a desirable level of appearance. The goal of most establishment projects, then, is to produce a turf stand that is dense, deeply rooted, and will provide rapid cover and develop to maturity as quickly as possible.

Turf establishment not only includes the act of planting, but also encompasses the period of time between planting and the point at which the turf reaches a reasonable level of maturity and appearance. This is commonly referred to as the **establishment period**. Specialized attention and practices are required during this period to help ensure a successful project. The length of the establishment period can vary considerably depending on many factors including site conditions, weather conditions, time of year, and turfgrass species/cultivars used.

A solid plan for any establishment project is critical. After a thorough site assessment and following proper turfgrass selection principles to match appropriate turfgrass species and cultivars to site conditions, user expectations, and resources for management, turf establishment has three general phases:

**Phase 1** – Site Preparation: evaluation, soil testing, cultivation, grading, amendments, seedbed preparation

**Phase 2** – Planting: seeding, sodding

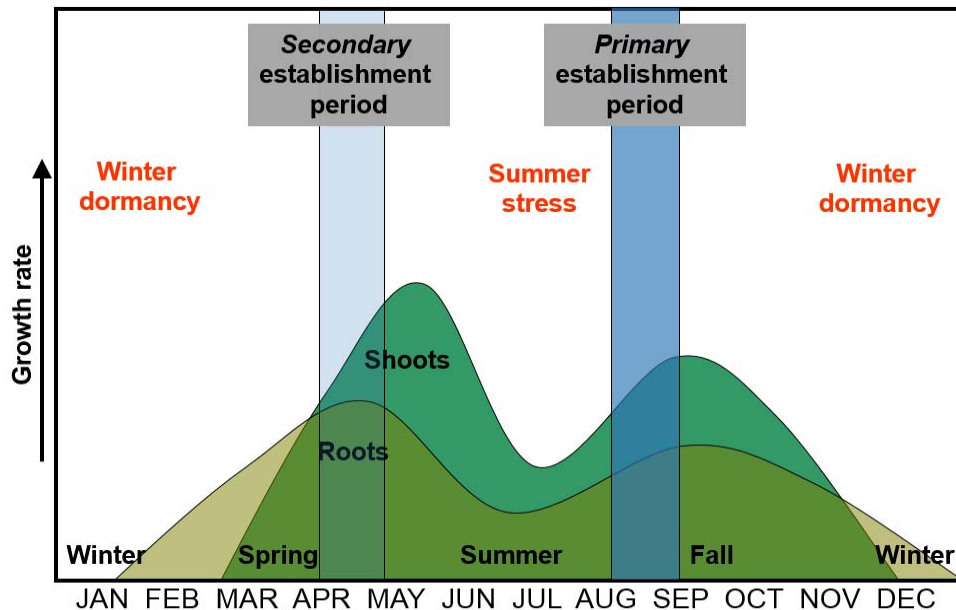
**Phase 3** – Establishment Period: post-planting care in terms of mulches, irrigation, mowing, and fertilizer.



## OBJECTIVE

Conduct all establishment projects at an appropriate time for the best chance of short- and long-term success.

### Cool-Season Turf Establishment Periods



**Plant during favorable periods whenever possible and avoid stress and pre-stress periods.**

- Temperature is key to the adaptation of grasses (*where* they grow well), as well as *when* they grow well (month to month and season to season).
- Cool-season turfgrass shoots grow best when air temperatures are in the range of 65°-75° F, and cool-season turfgrass roots grow best when soil temperatures are in the range of 55°-65° F
- Seasonal peaks in growth (spring and late summer) correspond with periods when temperatures are in the favorable range, and growth slows or stops during periods when temperatures are outside of this range (above or below).
- The most sensible approach, then, is to plant just ahead of the most favorable periods for growth, to align the establishment period with the best possible conditions.
- Whenever possible, avoid planting seed during stress and pre-stress periods (eg. late spring, summer, late fall). Planting during these periods greatly reduces the potential for long-term success, and greater inputs are often required.

**Recognize that late summer is vastly preferable to spring for planting of cool-season turfgrasses in New England.**

- Although a period of favorable growing conditions occurs in both spring and late summer in New England, a host of additional factors make late summer the ideal planting time:

	<b>Spring</b>	<b>Late Summer</b>
<b>Timing: *</b>	Best approach is to plant as <i>early as possible</i> , but opportunity varies based on winter/spring transition.	Best planting window approximately 3 <sup>rd</sup> week of August to 3 <sup>rd</sup> week of September, on average.
<b>Growth period exposure:</b>	Only one brief favorable growth period before the first onset of summer stress.	Two favorable periods before first onset of summer stress.
<b>Soil moisture:</b>	Typically wetter soils (more difficult to prepare). Less initial need for irrigation.	Typically drier soils (easier to prepare). More need for irrigation, particularly during early establishment.
<b>Soil temperature:</b>	Cooler soil temperatures.	Warmer soil temperatures.
<b>Precipitation and evaporative demand:</b>	Decreasing precipitation, on average, and increasing evaporation.	Increasing precipitation, on average, and decreasing evaporation.
<b>Weed competition:</b>	Increasing competition from annual, warm-season weeds, in particular crabgrass (herbicides normally required for control).	Little competition from germinating weeds (herbicides not typically necessary). Only winter annual weeds germinate in the fall.
<b>Herbicide conflicts:</b>	Seeding not compatible with applications of several common preemergence herbicides.	Preemergence herbicides not commonly applied/necessary during this period.
<b>Cultivation:</b>	Cultivation required for planting can stir the soil seed bank during the period of maximum annual weed seed germination.	Most appropriate time for annual cultivation practices, often performed in conjunction with planting.
<b>Deciduous trees:</b>	Deciduous trees leafing out = increasing shade.	Deciduous trees soon to drop leaves = decreasing shade.  Must take into account leaf drop on tiny seedlings.

\* In Massachusetts, appropriate times for establishment may vary on parts of Cape Cod and on the islands that warm later in the spring and stay warmer later into the fall.

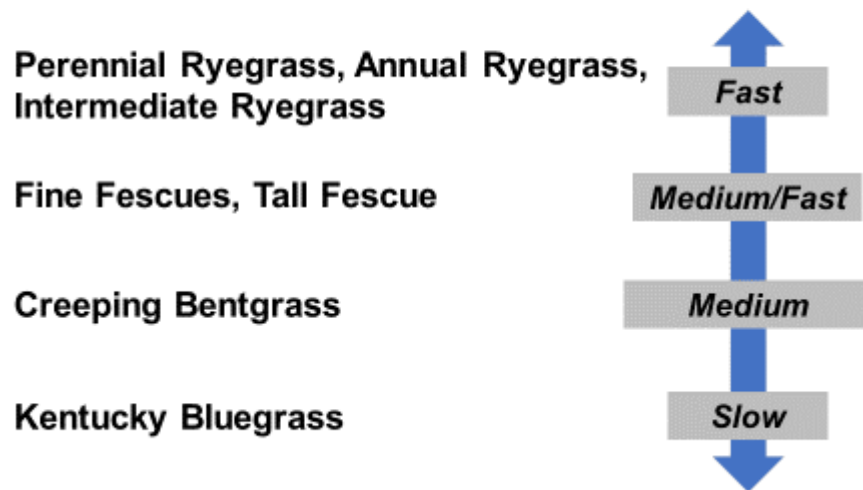


## Account for the establishment rate of the turfgrass species and cultivars used.

- The overall speed of turf establishment is affected by a number of factors including temperature, moisture, fertility, site conditions, etc.
- A key trait that influences the length of the establishment period is the inherent establishment rate of the turfgrass species and cultivars used.

In general, an establishment rate comparison by cool-season turfgrass species is as follows:

### Establishment Rate Comparison of Cool-Season Turfgrass Species



- Thus, slower establishing species, such as Kentucky bluegrass, should be seeded earlier during appropriate planting 'windows'.
- Slower species will require a comparatively longer period of specialized care during the establishment phase.
- With faster species, such as perennial ryegrass, more flexibility in terms of timing is possible.
- Faster establishing species are also better suited to overseeding or repairs, when factors such as competition with existing grasses or a great need for rapid cover come into play.

## Understand that expected returns begin to diminish rapidly in fall.

- In fall, average temperatures gradually decrease. Colder nights have an especially pronounced effect.
- Both day length and the angle of the sun are decreasing (shorter days and lower levels of available light = less photosynthesis = less vigorous growth and development).
- At some point in the fall, plant processes begin to shift away from growth and towards preparation for winter. Thus, grasses planted later in the season will be slower to establish, less hardy, and more susceptible to winter injury.

## What about dormant seeding?

- Dormant seeding is seeding after soil temperatures seasonally fall below the range in which seeds germinate (< 40°-45° F). Dormant seeding should not be attempted until temperatures fall below this range.
- When late-summer seeding is not an option, dormant seeding may or may not be as effective as an early spring seeding
- A gamble... don't count on it to work every time or as well as seeding at more desirable times! Best for emergencies and last resorts, as opposed to new projects.
- Follow-up seeding or overseeding may be needed in the spring in cases where conditions have not been favorable for a fully successful dormant seeding.

Dormant Seeding Pros	Dormant Seeding Cons
<ul style="list-style-type: none"><li>▪ Soils drier than in the spring, easier site preparation.</li><li>▪ Requires less irrigation attention.</li><li>▪ Requires less weed control attention.</li><li>▪ Can emerge earlier in spring and get a jump-start on weeds.</li></ul>	<ul style="list-style-type: none"><li>▪ A mid-winter warm-up can initiate germination.</li><li>▪ An open winter can dry out seeds.</li><li>▪ Better for slow-establishing species such as Kentucky bluegrass.</li><li>▪ Increased seeding rates are necessary (rule of thumb: increase by 50%).</li></ul>

## Pay special attention to weeds for spring establishment projects.

- When turf must be planted in the spring, one of the most significant challenges is competition from increasing annual weed pressure. A number of these weed species have warm-season or C4 physiology, which enables them to thrive under hot and dry conditions.

- Since cool-season turfgrasses are increasingly stressed under such conditions, warm-season weeds become increasingly and overwhelmingly competitive as spring progresses into summer. The first step to combat this problem with a spring seeding is to plant as early as possible.
- For the best chance of success, spring seedings are often performed in conjunction with application of pre-emergence herbicides.
- Several common pre-emergence herbicides *are not* compatible with seeding, and vice-versa, and many herbicides cannot be used post-emergence for a period of time as well. The few currently labeled herbicide materials that are compatible with seeding include siduron, mesotrione, and quinclorac.

For specific management approaches for spring weed control, refer to the [Weed Management](#) chapter of [UMass Extension's Professional Guide for IPM in Turf for Massachusetts](#).

 <b>OBJECTIVE</b>	<b>Properly prepare the planting site to promote rapid and complete establishment.</b>
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### **Have a sound plan for the project, starting with site preparation**

- Use information collected during site assessment to make site modifications, if needed.
- Establishment projects should include proper soil preparation, which includes soil testing.
- Since turf is a perennial system, new establishment projects or re-construction projects that 'open' the soil present a rare opportunity to fully incorporate lime, fertilizer, and other amendments into the root zone; to install sub-surface features such as drainage or irrigation components; and to alter the grade.

### **Test existing soil as well as soil or amendments which may be added to the site.**

- Test for chemical characteristics (pH, fertility, nutrient reserves, heavy metals, salinity, etc.).
- Test for physical characteristics (texture, particle size distribution, percent organic matter etc.).
- Ensure that any amendment materials are compatible with the soil already present on the site. Uninformed additions of soil or organic material are strongly discouraged and may lead to soil problems that are extremely difficult to solve.
- For comprehensive details on soil testing and soil fertility, refer to the [Soil and Nutrient Management](#) chapter of this document.

**Conduct site preparation activities in a manner that minimizes adverse environmental impact and results in no future compromise to the turf system.**

- Control all weeds, especially difficult perennial weeds.
- Remove all debris from land clearing and similar operations; never bury debris. Debris left to decay in the soil may result in future problems such as fairy rings, proliferation of mushrooms, poor drainage, depressions, and stress spots or failures.
- Minimize the area of soil exposed as well as amount of time that soil is bare.
- Protect any exposed soil from erosion. Use temporary groundcovers or cover crops if land will be bare for an extended period. Cover stockpiled soil, and do not leave soil exposed over winter.
- Protect entryways to water resources (i.e. catch basins and other drainageways) from runoff from exposed and stockpiled soil or amendments. Environmental protection measures may include installation of erosion control barriers such as straw bales, silt fences, berms, compost filter socks and sediment basins. Maintain protection until turf is well established.
- When conducting sitework with heavy equipment, remove and stockpile topsoil and/or bring in new topsoil. Mix soil and amendments off-site to reduce compaction concerns.

**Grade properly.**

- Provide for proper water movement and drainage.

**Surface drainage:** movement of water across the top of the soil, via directed slope.

**Internal drainage:** downward movement of water into, through and out of the soil profile and drainage features.

- When grading, it is especially important to consider a range of scenarios, from regular precipitation to extreme storm events, to help ensure that water will move off the site in an effective and environmentally responsible manner under a variety of conditions.
- When rough grading, match contours of sub-grade to desired finished grade.
- Install underground irrigation and drainage components beneath the sub-grade.
- Eliminate depressions and pitch the grade away from buildings.
- Avoid altering the grade around established trees to prevent damage to the root system (no cutting, no filling)
- Compaction caused by construction activities should be remedied before topsoil is replaced
- Allow for soil to settle before final grading. Final grading should be done just prior to final bed preparation for seeding or sodding.



*Judicious use of surface drainage features can prevent excess moisture problems and pooling and ponding of water.*

**Provide for irrigation and sub-surface and surface drainage if necessary.**

- Install any sub-surface irrigation components prior to planting if specified and appropriate for the site and the management program.
- Where surface drainage is not sufficient and where otherwise warranted, sub-surface drainage should be installed.
- Where possible, and when it will not interfere with the use of the turf, grade to allow turf to take advantage of runoff from impervious surfaces such as parking areas, driveways, and rooftops.


**Prepare the root zone.**

- An ideal root zone for a lawn is friable, fertile, and has good infiltration, drainage and water holding capacity.
- Provide for a minimum 6 inch depth of root zone.
- When using existing soil incorporate amendments, fertilizer and liming materials as specified by results of a soil test. Refer to the [Soil and Nutrient Management](#) chapter of this document for additional information.
- When amending existing soil, rototill in small amounts at a time to achieve uniform distribution.

- Note that excessive rototilling or rototilling when the soil is wet can damage soil structure.
- Whenever possible, and when amending with large quantities of materials, remove topsoil and mix with amendments off-site, then replace uniformly mixed/amended soil.

### Prepare the final planting bed.

- The final objective is a firm (not compacted), granular bed for seed or sod.
- Remove all rocks and debris and ensure a uniform surface.
- Drag or hand rake the site if necessary.
- Irrigate lightly to settle the soil, or roll lightly to firm if needed.

 <b>OBJECTIVE</b>	<b>Use a planting method that is appropriate for the site, the budget, and project objectives.</b>
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### SEEDING

**Know that the single most important investment in ensuring high quality turf is the use of high quality seed.**

- Seed cost is relatively low when compared with other turf management inputs.
- An investment in high quality seed is relatively small when the potential number of years that a turf stand can persist is considered, as well as the reduction in management inputs often realized with higher quality turf.

### Read and understand turfgrass seed labels.

- To inform and protect the buyer, certain information must be listed on the seed label:
  1. **The name of the seller**
  2. **The lot number:** can be used to track the origin of the seed. Useful if a problem develops.
  3. **The seed variety or varieties:** in some cases it is legal to list species with only VNS (Variety Not Stated) designation.
  4. **Pure seed content (purity):** % by weight of each species or variety. A measure of seed *quantity*, not quality.
  5. **Germination percentage:** % of each pure seed component that was capable of growth at the time of testing (under ideal conditions).
  6. **Date:** the date on which the seed was tested. Germination percentage declines with age of the seed.
  7. **Crop seed content:** Can be more undesirable than weed seeds as a source of contamination. Should be as low as possible!

8. **Weed seed content:** % of all seeds that are not pure seed or crop seed. Ideally 0.5% or less.
9. **Noxious weeds:** expressed as per pound or per ounce of content weeds officially classified as difficult to manage.
10. **Inert matter:** % by weight of all material in the seed that will not grow. Lower inert matter = better value!

For more information, refer to our [Understanding a Turfgrass Seed Label](#) fact sheet.

### Use certified seed whenever possible.

- Certified seed must meet minimums for purity and more rigid standards for weed and crop seed content.
- Seed certification helps to guarantee authenticity of turfgrass varieties.
- Certified seed carries a color-coded certification tag: blue tag = 95% purity, gold tag = 96-97% purity.

### Determine and use an appropriate seeding rate.

- Proper seeding rate is critical to achieving a functional turfgrass stand that will develop to maturity as quickly as possible.
- Turfgrass plants compete for space and resources with each other and with potential invaders (weeds).

Lower than optimum seeding rate =	Higher than optimum seeding rate* =
An open stand of low shoot density which is less functional and encourages weed invasion.	A stand composed of many small plants that are slow to mature and less tolerant of stress.

\* Please note that high rate overseeding and repairs, when done properly, is an accepted and successful practice in many sports fields management programs.

- Optimum seeding rate ranges take into account factors such as: seed size and number per pound, growth habit, minimum purity and germination differences among species.

Large seeds = less seed per pound = higher seeding rate

Small seeds = more seed per pound = lower seeding rate

- Growth habit affects seeding rate: adhering to at least minimum seeding rates is important with bunch-type grasses, which have a lower capacity to spread laterally relative to stoloniferous or rhizomatous grasses.
- The better the conditions for seeding (soil type, seedbed, time of year) the less seed will be needed.
- As a general rule, seeding rates should be increased by 50% to compensate for poor conditions.

**Factors or conditions that contribute to poor germination and seedling survival include:**

- **poor soil conditions**, including drainage (excessive or poor), improper pH, nutrient deficiency, compaction, salinity.
- **poor seedbed** because of inadequate or excessive soil firming, excessive tilling, rocks and debris at soil surface, poor seed to soil contact or coverage, inadequate or excessive mulch, or steep grades that contribute to soil erosion.
- **less than optimum seeding time**, causing late spring/early summer mortality (drought and heat stress, weed competition, and disease) or late fall/early winter mortality (winter desiccation, frost heaves, unfavorable temperature).
- **poor post planting care**, consisting of inadequate soil moisture (irrigation), improper mowing and fertilization practices, not controlling traffic, etc.

For specific seeding rate guidelines for turfgrass species and recommended mixtures, refer to the [Turfgrass Selection: Species and Cultivars](#) chapter of UMass Extension's [Professional Guide for IPM in Turf for Massachusetts](#).

**Use an appropriate and effective seeding method.**

- Maximize seed to soil contact through every avenue available.
- Divide seed in half and seed in two directions when possible for maximum coverage and uniformity, using equipment appropriate to the particular site and operation.
- Drop spreaders are somewhat preferred for precise application (better suited for tight areas and around non-turf areas), rotary spreaders are less precise (better suited for larger, open areas).
- Spreader calibration is seldom practical for seed. A general guideline is to start at 20% open/80% closed and adjust as needed (seed is much more forgiving than fertilizers or pesticides).
- Seed 'drills' (Brillion seeders) are very precise, but best suited for large areas and sod farms
- Seeding by hand is imprecise and should be avoided with the exception of small repairs.
- Consider the use of hydroseeding on large or hard to access areas.
- Careful attention to turfgrass selection, proper use of quality mulch materials, correct application methods, and good follow-up care lead to better long-term results from hydroseeding. For example, contrary to popular belief, the use of hydroseeding does not typically eliminate the need for careful irrigation during the establishment period.



Hydroseeding Pros	Hydroseeding Cons
<ul style="list-style-type: none"> <li>▪ Fast, large areas can be seeded quickly.</li> <li>▪ Especially suited to difficult sites such as roadsides, medians, and steep slopes.</li> <li>▪ Addition of mulch and ‘tackifier’ can help with erosion control.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Higher cost than standard seeding</li> <li>▪ Relatively poor seed-to-soil contact.</li> <li>▪ Risk of mulch drying out and forming a hard crust which can inhibit seedling development</li> </ul>

## SODDING

**Consider establishment from sod if the site, project and budget allow.**

- Sodding involves transplanting of turf from one site to another.
- Fast and effective, but expensive compared to other establishment methods.
- Can provide opportunities for establishment at times that would otherwise be less than ideal. Sod laid in spring, for example, is better able to compete with annual weed pressure than turf planted from seed.
- Most appropriate for high value sites, or situations where turf cover is needed very quickly.

**Use appropriate methods for sod installation.**

- Specialized care for handling and establishment are required. Sod must be installed ASAP after harvest (normally within 24 hours). Prevent sod rolls or pieces from drying out and protect from overheating prior to installation.
- Sod can be installed any time soil is not frozen (for best results, soils should be warm enough for root growth: > 50° F).
- Soil on sod should be as close as possible to soil on site; this reduces the potential for layering problems.
- Site preparation is the same as for seeding (finished grade; lime and fertilizer according to soil test; firm, granular planting bed), with the planting bed being slightly firmer, but not compacted.
- Moisten (don’t soak) sod prior to installation.
- Lay sod by staggering the seams, perpendicular to slope. Stake or staple on slopes greater than 10%.
- Roll sod lightly to eliminate air pockets and ensure soil contact.
- Irrigate sod deeply as soon as possible after installation, enough to wet the underlying soil and promote good rooting and establishment.
- Fill in any seams that open with seed/soil/compost “divot mix”.
- With sod, post-plant fertilizer applications must be delayed until the root system is well developed and has knit strongly into the existing soil.



*When laying sod, seams should be pulled tightly closed. Proper repair steps should be taken for seams that open after installation.*

**Pay attention to sod thickness for specialized installations.**

- Sod thickness refers to the amount of soil attached to the sod and does not include shoots or thatch.
- Sod is often available in various thicknesses, typically ranging from 1/2" to 2", and also various widths.
- Different sod thicknesses suit different applications:  
Thinner sod = lower cost = lower initial stability = faster establishment  
Thicker sod = higher cost = higher initial stability = slower establishment
- Thicker cut sod is most often used for specialized installations (typically sports fields), and is not necessarily appropriate for lawns.



## OBJECTIVE

**Provide attentive post-planting care to promote turf growth and development during the establishment period.**

**Understand that careful attention to moisture during the establishment period is a critical aspect of any planting project.**

- Adequate moisture is required not only to initiate the seed germination process, but also to sustain young seedlings before their root systems are fully developed. In the case of sod, adequate moisture is necessary for the sod to root down into the soil on the site.
- Too *little* water will cause seedlings or sod to dry out, which could result in delayed development or death of plants.
- Too *much* water can inhibit germination, rooting and shoot growth, promote disease problems ('damping-off') and may cause washing of seed and soil.
- The general approach is to keep the planting site evenly moist but not soggy, and to gradually scale back irrigation as the turf, in particular the root system, develops and matures.
- At first, water frequently to a shallow depth. As seedlings mature, reduce the frequency of irrigation, but increase duration of each irrigation event to water more deeply, eventually recharging the root zone and allowing the top of the soil to dry between irrigation events.

**Use compatible mulches when planting from seed to enhance establishment and protect the soil.**

- The best mulches are weed-free, bio-degradable, and non-smothering.
- Mulches can be used during establishment to:
  - Retain moisture, and help with tricky water management
  - Help prevent soil erosion, especially on slopes
  - Protect seed/seedlings from movement due to washing or wind (keep seed in place)
  - Protect seed/seedlings from foraging animals or birds
  - Buffer temperature fluctuations

- Mulch types:

<b>Loose 'straw' mulches</b>	Seek out 'clean' straw such as oat or barley. Avoid local 'hay' due to high potential for undesirable weed seeds.
<b>Straw and wood-fiber netting:</b>	Fast, uniform coverage, but higher cost than loose straw options. Very good erosion control. Most are bio-degradable, leave-in-place systems.
<b>PennMulch™ or similar products:</b>	Made from recycled newspaper and include water-holding polymers, similar to hydroseeding mulch.



*During establishment, clean, weed-free mulch materials can conserve moisture and help to hold seed and soil on a slope.*

**Pay particular attention to fertility during the establishment period.**

- Establishing turf uses available nitrogen very quickly. Watch for slow growth, yellowing, and other signs of nutrient deficiency.
- Maintain fertility, especially N, to maintain vigorous growth and prevent deficiency.
- Rule of thumb: apply an additional 0.5 lbs N/1000 ft<sup>2</sup> when establishing turf is 2-3 inches high.


- In the case of sod projects, post-plant fertilizer applications must be delayed until the root system is well established. This process may take up to six weeks, or longer. Nutrients applied too soon will not benefit the plants and have a higher probability of loss to leaching and runoff.

**Begin mowing as soon as the turf can withstand traffic.**

- Mowing is a key step for turf establishment, as mowing stimulates tillering which is the primary driver of turf density.
- When dealing with new turf, the best way to time the first mowing is to use the '1/3 rule' as a general guideline.
- Accordingly, an appropriate mowing height should be determined in advance, and the turf should be cut when it reaches a height around the 1/3 rule threshold. In other words, when seedlings reach a height about 1/3 higher than desired lawn height, and can withstand traffic, begin to mow to a height appropriate for the species and use.
- If concern exists about traffic or compaction on the site, opt for smaller lighter walk-behind equipment for the first few mowings, as opposed to larger, heavier riding equipment.
- The 1/3 rule can also be used to determine the appropriate mowing frequency as the turf matures.

**Stay on top of weeds.**

- When feasible, mechanically remove weed infestations from newly established lawns.
- Annual weeds will eventually mow out of new turf.
- Do not apply weed control materials until turf is well established - a minimum of three mowings.
- Follow label instructions of any herbicide carefully to avoid damaging young turfgrass plants. Spot treat whenever possible.

 <b>OBJECTIVE</b>	<b>Re-plant when turf performance deteriorates below an acceptable level and cannot be improved through normal cultural practices.</b>
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**Choose a re-planting approach that fits the situation.**

- There are two general categories of re-planting:

**Renovation** (*less disruptive*) – Process of replacing the turf plants on a site without making changes to the soil or grade. Does not normally include total removal of existing turf, but usually includes eradication of the existing stand with non-selective herbicides or extended covering. May include some superficial cultivation in the interest of promoting seed-to-soil contact.

**Re-construction** (*more disruptive*) – Involves wholesale removal of existing turf on a site in conjunction with tilling or other soil cultivation, at least to the depth of the root zone or deeper. Frequently includes addition of soil amendments, addition of topsoil, and/or changes to grade.

**Choose renovation when turf has deteriorated due to stress, pest damage or unadapted grasses, but the soil and overall growing environment remain generally suitable.**

- A general guideline is to renovate when 50% or more of the turf is composed of undesirable grasses or weeds.
- Renovation is a great opportunity to more closely match grass species and varieties to site conditions.
- When circumstances or budget do not permit a justifiable re-construction, a renovation approach will most often yield measurable improvement.
- Even in situations where the means and need for re-construction exist, opting for renovation first can delay major disruption and may at best have satisfactory results and at least buy some time (perhaps multiple seasons) before the larger investment of funds and energy in a wholesale re-construction project.
- Time renovation projects to coincide with an opportune time for turfgrass growth and development.

**Evaluate the site prior to beginning the renovation process, and correct any factors that may have contributed to the turf deterioration.**

- The turf may be in poor condition because of unadapted grasses, extensive thatch accumulation, excessive disease and/or insect damage, a heavy infestation of difficult-to-control weeds, or a number of other factors.
- An important step in renovation is to eliminate whatever factors caused poor quality, followed by re-planting. Renovation will only yield temporary improvement unless the original factors that led to poor quality are remedied.

**Control all weeds present prior to planting.**

- Most broadleaf weeds can be selectively eliminated by using commonly available herbicides. When infestations are small, spot treatments may be effective.
- Follow label directions for appropriate intervals following herbicide application before proceeding with renovation in order to allow for complete herbicide uptake and allow any chemical residues in the soil to dissipate.
- It may be advisable to permit the lawn to grow slightly higher than normal prior to weed control to allow the weeds to grow larger, thus producing more leaf area for better herbicide uptake and control.
- Small infestations of bunch type (non-spreading), weedy grasses can be removed by digging. Remove the weedy grass and soil to a depth of about 2 to 3 inches. Remove soil for a distance of about 2 to 3 inches outside of the clump to ensure the removal of all parts of the undesirable plant. Spot treatments with a non-selective herbicide that allows for seeding quickly following treatment may also be effective.

- Perennial weeds which spread via rhizomes (underground creeping stems) or stolons (above ground runners) cannot be controlled by digging, and are more effectively controlled using a non-selective herbicide.

### **Fertilize and lime if necessary.**

- Proper soil fertility and pH are essential for successful renovation.
- Application rates of fertilizer and lime should be based on soil test results. For more information, refer to the [Soil and Nutrient Management](#) chapter of this document.
- Obtain a soil test at least 3 to 4 weeks prior to renovation, if possible.

### **Prepare the seedbed.**

- Mow as low as possible, somewhere in the range of 1/2 inch to 3/4 inch is ideal.
- If there is an appreciable accumulation of thatch (especially if more than 1/3 inch), remove it at this time using a de-thatcher, power rake or vertical mower.
- To provide a good seedbed and help ensure good seed-to-soil contact, use a de-thatcher set to penetrate the soil to a depth of about 1/4 inch. Smaller areas can be hand-raked to loosen the soil to the proper depth.
- When raking or dethatching, do not remove more than 50 percent of the dead debris because the remaining debris serves as mulch, which protects against soil erosion and seed displacement, and helps with moisture retention.
- Remove all loose debris prior to seeding.
- Power slice seeding is an additional, very effective approach that combines the cultivation and planting steps and yields superior seed-to-soil contact.

### **Seed the area.**

- Use seed from a mix or blend similar to that existing in the lawn unless improper turfgrass selection was the original cause of poor quality. In the latter case, match new species and cultivars to the growing environment on the site, the intended use of the turf, and the management program (see the [Turfgrass Selection: Species and Cultivars](#) chapter of UMass Extension's [Professional Guide for IPM in Turf for Massachusetts](#))
- Apply seed uniformly over the area to be renovated. In order to insure uniform coverage, apply the seed in two directions made at right angles to each other.
- Rake lightly following seeding (a leaf rake works well), or drag with a steel mat or door mat to work the seed into the soil to a depth of about 1/4 inch.
- Roll the area if possible to insure good seed-to-soil contact.
- If the area being renovated is on a slope, application of weed-free mulch may be necessary to prevent erosion.

### **Provide follow-up care for the site.**

- Water lightly and frequently, two to three times per day if necessary, to keep the seed bed damp during the period of germination and establishment.
- When seedlings reach a height about 1/3 higher than desired lawn height, and can withstand traffic, begin to mow to a height appropriate for the species and use.

**Consider full-scale re-construction when there are ongoing problems that go beyond just the plants present.**

- Re-construction provides opportunities not typically available in a perennial turf system including ability to incorporate fertilizer and soil amendments, improve drainage, and alter the grade.
- In other instances, digging may be required to remove boulders or buried debris, or to install physical infrastructure such as irrigation system components.
- Compared with renovation, re-construction is more expensive, time-consuming, labor intensive, and functionally and aesthetically disruptive.
- Cultivation can damage soil structure, introduce the possibility of soil erosion, and stir the 'seed bank'.
- In the majority of circumstances, therefore, complete re-construction should be based on identifiable need or, from a strictly agronomic perspective, treated as a last resort.

**After tillage and eradication of existing turf, the steps for re-construction are identical to the practices for new establishment outlined in the first part of this chapter.**

 <b>OBJECTIVE</b>	<b>Use specialized establishment practices to effectively maintain turf cover and density.</b>
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**Overseed regularly to maintain adequate turf cover and density.**

- Overseeding is the process of introducing seed into a living, often established stand of turf, in order to make repairs or to maintain adequate turf density.
- Overseeding is a key practice on heavily-trafficked areas and sports fields.
- When overseeding is performed to gradually introduce different grass species or cultivars and alter the stand composition over time, it may also be referred to as **interseeding**.

**Use effective overseeding methods.**

- Like renovation, overseeding requires superficial cultivation to promote seed-to-soil contact.
- Common approaches include broadcast seeding following disruptive practices such as aeration, dethatching, or topdressing.
- Power slice seeding is a very effective, efficient, and minimally disruptive overseeding method.

**Take turfgrass selection into account when overseeding.**

- Because of competition with existing, living turf, faster-establishing turfgrass species such as perennial ryegrass are best-suited for overseeding.



- Slow-establishing grasses, particularly bluegrasses, are more challenging to overseed successfully.
- For better results with slower grasses, suppress existing turf with moderately close mowing prior to overseeding.
- Continue mowing regularly; base mowing frequency and height of cut on mature grasses present.

### **Repair thin or bare patches regularly, on an as needed basis.**

- Loosen soil if necessary or aerate with core aeration or vigorous raking. 'Garden Weasel' type cultivators are an excellent tool for small patches.
- Apply seed.
- Topdress with fine finished compost or mulch.
- Irrigate in the same manner as for new seedings.

### **Pre-germinate seed for very quick repairs.**

- Place seed into a cloth sack.
  - Submerge sack into a bucket or barrel of water and soak for at least 12 hours. Sufficient time may vary depending on grass species selection.
  - Aerate by lifting the bag out of the water and placing it back several times every few hours, or bubble air into the water.
  - Spread seed out to dry it sufficiently for application in a drop or rotary spreader or a slice seeder.
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## SECTION 6

### IRRIGATION AND WATER MANAGEMENT

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#### OBJECTIVE

**Reduce water use for turf management to the lowest possible level to conserve and protect our most precious natural resource.**

#### **Implement water conservation strategies for both economic and judicious reasons.**

- The demand for potable water (drinking water) for agricultural, residential, and industrial use is expected to increase in the future while our supply of water will remain essentially unchanged.
- When rainfall is insufficient and water resources become limited, supplemental irrigation required to sustain plantings such as lawn and landscape turf is often the first to be placed on water use restrictions.
- Comply with local and state water use regulations and restrictions.

#### **Reconsider the replacement of turf areas with tree and shrub plantings.**

- The use of trees, shrubs and other ornamental plantings in the landscape in lieu of turf does not necessarily suggest low water use or minimal maintenance.
- In studies that are available, which compare water use or evapotranspiration (ET), trees and shrubs have been regularly found to be higher water users than turfgrass.

**Example:** on average, one mature oak tree has water requirements equivalent to 1800 ft<sup>2</sup> of turf. This in large part is due to the greater leaf canopy surface area that is exposed to atmospheric (evaporative) demand.

- Adjacent trees and shrubs in the landscape commonly benefit from irrigation applied to turf.

#### **Be familiar with the concept of evapotranspiration (ET).**

- Evapotranspiration is the sum total of water lost to the atmosphere due to evaporation from the soil surface plus transpirational water loss associated with leaf surfaces.
- In high quality turf where 95% of the soil surface may be shaded by leafy vegetation, the major contributor to ET is transpiration.
- ET increases with increasing solar radiation, high temperatures, wind, and decreasing relative humidity.

**Select turfgrass species and cultivars with demonstrated water use efficiency when possible and appropriate.**

- Many modern turfgrass varieties have been developed to provide acceptable function and quality with reduced water input.
- By selecting turfgrass species (and cultivars) that have scientifically documented low water requirements or superior drought resistance, the turfgrass practitioner can delay or postpone drought stress injury and associated decline in turfgrass quality and function during extended periods of little or no water.
- Turfgrass species and cultivars with low leaf area (slow growth rates, narrow leaf width), high leaf and shoot densities, and horizontal leaf orientation use less water. Kentucky bluegrass varieties can vary by as much as 30% in their ET rate due to these plant (morphological) factors.
- Low water use does not necessarily equate to superior drought resistance because rooting depth is also an important drought resistance component.



**OBJECTIVE**

**Carry out management practices with responsible water use as a priority.**

**Minimize supplemental irrigation to the lowest level required for turf function and quality.**

- Irrigation should be initiated at the onset of mild drought stress to recharge the root zone unless dormancy is the desired goal.
- Incorporate hand watering into the management program when appropriate.
- Irrigation should be timed in order to minimize duration of leaf wetness so as to reduce the incidence of diseases.
- Test water for irrigation suitability. Water department or board of health test results can often be accessed for this information.
- Maintain and adjust irrigation systems according to weather conditions.
- Supply adequate water for establishment, renovation, repairs, and overseeding.

**Follow the '1/3 Rule' when scheduling mowing events.**

- Regular and frequent mowing helps to minimize water loss through reduced leaf area and turfgrass ET.

**Maintain sharp mower blades.**

- Dull mower blade injury can increase water use by delaying the healing of open wounds following mowing events. These wounds also promote disease infection.



*Irrigate judiciously to promote optimum turf health and protect water resources.*

### **Raise the height of cut (HOC) as summer progresses.**

- Higher mowing heights promote deeper rooting and therefore access to greater amounts of soil water. This is especially true in spring when 60% of the total annual root mass is produced.
- Keep in mind that higher HOC can increase leaf area and hence ET losses during hot and dry conditions. Irrigated turf may be able to withstand lower HOC in summer than non-irrigated turf.

### **Apply fertilizer nitrogen at minimal levels timed to specific needs of turfgrass.**

- Nitrogen (N) promotes leaf area (and ET) and reduces rooting depth, thus increasing the need to irrigate.
- Nitrogen, especially water soluble N, must be kept to its lowest possible level needed to sustain turf function.

### **Apply potassium in balance with nitrogen.**

- Potassium (K) is a nutrient that is important to turf during stress periods.
- Soil testing is needed to identify K deficiencies. If soil K levels are adequate based on a soil test, then K should be applied at levels that are approximately 50% to 75% of the total annual N.

### Apply herbicides intelligently.

- Herbicides should be applied only as needed and according to label directions.
- Preemergence herbicides have a greater impact on roots than on shoots. Hence, turfgrass shoots may be unaffected while root activity is severely reduced.
- Use split applications of soil-applied preemergence herbicides when appropriate to reduce the potential for adverse effects on turfgrass roots.
- Spot treat for broadleaf weeds, when possible, to limit stress; avoid blanket applications of herbicides when air temperatures exceed 85 °F.

### Alleviate root-related stresses.

- Research has shown that deep rooting may play a more important role in water conservation and drought resistance than low ET.
- Factors that inhibit rooting can increase the need to water.
- Factors that inhibit rooting include acidic soil pH (< 5.5), excess thatch (greater than ½ inch), inadequate depth of soil for root zone, soil compaction, over-watering, excessively close mowing, excess N fertilization, and high soil temperature.
- Two or more root-inhibiting factors in combination can significantly reduce rooting depth more than any single factor when considered alone.
- Compaction and thatch are especially problematic because these conditions also promote runoff, which reduce irrigation efficiency and increase environmental impact.

### Monitor and manage thatch accumulation.

- Manage thatch effectively. When levels exceed ⅓ to ½ inch, consider corrective action to promote deeper rooting into the soil and to limit rooting that is confined to the poor nutrient and water holding environment of the thatch.

### Eliminate competition for plant available soil water.

- Remove all weeds that compete with turfgrass for limited plant available water.
- Design landscape plantings to minimize adverse interactions.
- Prune roots of trees near turf areas if possible to prevent tree roots from competing for nutrients and water.

### Plan irrigation scheduling based on evapotranspiration (ET).

- This prevents over-watering (leaching and runoff losses) and under-watering (shallow rooting) of turf.

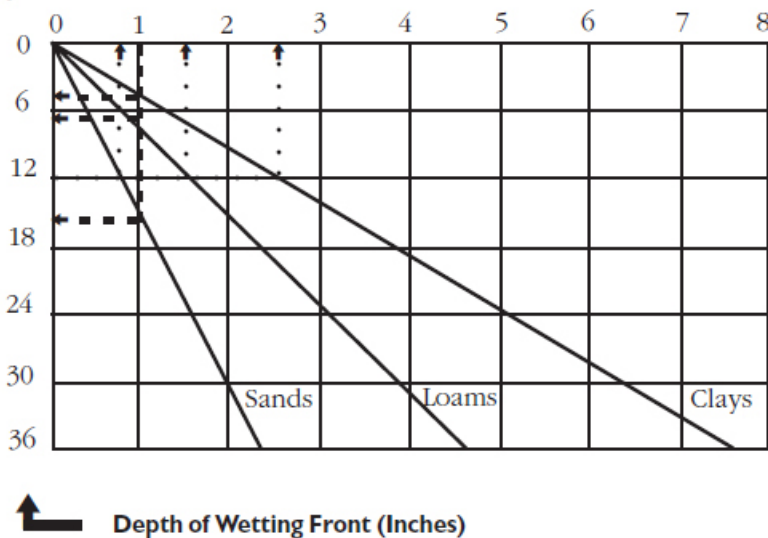
**Example:** On average, a Kentucky bluegrass turf will lose approximately 1.4 inches of water per week as ET during the irrigation season (July and August).

- Irrigation systems can be fitted with ET signaling controllers. Additional water savings of 20% are possible, as research has shown that acceptable turf quality can be maintained by replacing just 80% of water lost as ET.

## Know your soil type.

- Sands hold approximately half as much plant available water as loam soils and soils high in clay, and therefore sands must be irrigated more often.
- Compacted soils and soils high in clay exhibit low soil infiltration rates, which promote surface water runoff.
- Irrigation systems can be fitted with features that permit multiple cycling so that irrigation (ET replacement) amounts are applied using short, repeated cycles. This multiple cycling increases water infiltration, prevents runoff, prevents erosion, and reduces waste.
- Heavier soils (loams, clays) and soils with a high percent of organic matter will retain water for a longer period than sandier soils.

**Inches of irrigation water required to wet soil to a predetermined depth.**



**Example:** Using the chart above, one inch of water (indicated by the dashed line) applied to a clay soil would wet the soil to field capacity to a depth of approximately 5 inches; a loam to a depth of approximately 7 inches; and a sand to a depth of approximately 15 inches. Equivalently, to wet a soil to a depth of 12 inches (indicated by the dotted line) 0.75 inches of water is needed for sands; 1.5 inches of water for loams; and 2.5 inches of water for clays. Hence, it takes more than 3 times as much water to recharge a clay soil to field capacity to a 12-inch depth compared to sands as a result of the greater soil moisture-holding capacity associated with fine textured soils.

## Eliminate waste.

- Irrigation systems that include rain sensing override devices can eliminate unnecessary irrigation during rainfall events.
- Turf areas irrigated on narrow strips are difficult to water efficiently without promoting wetting of non-grassy areas, and therefore should be avoided, or should have irrigation systems designed to apply water without waste.
- Irrigating during calm periods such as early morning can promote more uniform

distribution of water and reduce evaporative and off-target losses.

- Clean up sidewalks and paved areas following maintenance operations by sweeping rather than by spraying with a hose.
- Correct areas of poor drainage to reduce pooling and ponding of water.
- Adjust systems to minimize irrigation that reaches impervious surfaces and repair all leaks as soon as detected.



*Use multiple short irrigation cycles to increase water infiltration, to prevent runoff, to promote efficient use of irrigation water, and to avoid the problems shown here: wetting of non-grassy areas and hard surfaces, and waste of precious water resources.*

### **Water deeply and infrequently.**

- Water to fully recharge the plant available soil moisture pool and to insure that soil is wet to the maximum rooting depth. This is best achieved by irrigating according to ET.
- Rooting depth declines as summer progresses with increasing soil temperature. Inspect for proper soil wetting depth and rooting potential by soil sampling.
- Allow for mild drought stress (leaf roll/fold, foot printing) to occur between irrigation events to promote deeper rooting and drought resistance.
- Maintaining root zones at field capacity by over-watering will inhibit rooting, decrease drought resistance, and promote disease and soil compaction.

### **Maximize the amount of water that enters the root zone.**

- Address conditions that reduce soil infiltration rates such as soil compaction, thatch, and hydrophobic soils.
- Under conditions associated with low infiltration the necessary amount of water should be applied using several short cycles or multiple irrigation events (referred to as multiple cycling), rather than applying all the water in one event.
- Irrigation should be scheduled when wind conditions are minimal in order to achieve a more uniform application.



#### **OBJECTIVE**

**Manage for drought dormancy when the management program and user expectations allow.**

### **Take measures to ensure recovery when lawn areas are allowed to enter drought dormancy, especially when accompanied by high heat.**

- Do not mow unless absolutely necessary.
- Strictly limit foot and vehicle traffic.
- Continue monitoring for pest infestation (chinch bugs, grubs, weeds). Manage damaging insect populations if needed.
- Do not fertilize dormant turf; fertilize when cool weather and moisture return, and when growth resumes.
- Plan to overseed damaged areas.





*Limit foot and vehicle traffic on drought-stressed and dormant turf to avoid the potential for injury. The damage to this heat and drought stressed turf is from a child's toy, not an automobile.*



**OBJECTIVE**

**Ensure that irrigation systems are properly designed, installed, and maintained.**

**Note:** The following irrigation system BMPs are adapted with permission from ***BMPs for Turf and Landscape*** published by the Irrigation Association (IA). A detailed and complete version of the document including associated **Practice Guidelines** is available on the IA website at: <http://www.irrigation.org/>

**Assure overall quality of the irrigation system.**

- The purpose of an irrigation system is to provide supplemental water when rainfall is not sufficient to maintain the turf and landscape for its intended purpose.
- Sound water delivery and management practices are necessary to distribute water to adequately maintain plant health while protecting water resources and the environment.
- Assuring the overall quality of the system requires attention to system design, installation, maintenance and management.

## **Guidelines for irrigation system design, installation and management:**

- The irrigation system should be designed to be efficient and to uniformly distribute water.
- The irrigation system should be installed according to the design specifications.
- The irrigation system should be regularly maintained to preserve the integrity of the design and to sustain efficient operation.
- The irrigation schedule should be managed to maintain a healthy and functional landscape with the minimum required amount of water.

### **Design the irrigation system for the efficient and uniform distribution of water.**

- Specific criteria that should be considered in the design include soil type, slope, root depth, plant materials, microclimates, weather conditions and water source (e.g., quantity, quality and pressure).
- To conserve and protect water resources, the irrigation designer should select appropriate equipment components that meet state and local code requirements and site requirements.

### **Install the irrigation system to meet the design criteria.**

- To conserve and protect water resources, the installed components shall meet the irrigation design specifications, manufacturer's specifications, and state and local code requirements.
- The installation should result in an efficient and uniform distribution of water.
- The irrigation contractor or installer shall be licensed and/or certified where applicable, and insured.

### **Maintain the irrigation system for optimum performance.**

- The irrigation system should be regularly serviced to maintain the performance of the system as designed.
- To conserve and protect water resources and the environment, the serviced components should meet the irrigation design specifications, manufacturer's specifications, and state and local code requirements.
- The maintenance should result in sustaining an efficient and uniform distribution of water.
- The maintenance contractor, owner, manager, or irrigation contractor shall be licensed and/or certified where applicable, and insured.

### **Manage the irrigation system to respond to the changing requirement for water in the landscape.**

- To conserve and protect water resources and the environment, the irrigation schedule shall be changed as required to provide supplemental water to maintain a functional, healthy turf and landscape with the minimum required amount of water.

## SECTION 7

### SOIL & NUTRIENT MANAGEMENT

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Developing and implementing a soil and nutrient management plan is critical to the proper management of turf with environmental protection and enhancement as priorities. The term 'nutrient management' infers a responsibility common to all turf practitioners that goes beyond simple additions of fertilizer in efforts to positively influence plant growth. In the interest of environmental protection, natural resource preservation, and economic viability, modern fertility programs necessitate custodial responsibility for the fate of applied nutrients in the environment and complementary practices designed to enhance nutrient efficiency.

Nutrient management for turf involves:

- Analysis of the existing condition and fertility of the soil that provides the growing medium for the turf and influences site characteristics such as drainage and water infiltration.
- Careful consideration of the nutritional requirements of the turf, based on several variables including soil fertility, expected quality of the turf, use of the turf, suitability of the growing environment, grass species and varieties present, and available management resources.
- Awareness of the potential for adverse impact from nutrient contamination on precious natural resources, particularly water, from off-site movement of nutrients due to factors such as misapplication, runoff, erosion and leaching.
- Informed and judicious additions of nutrients into the turf system with regard to proper timing, proper application rate, proper material selection, and proper placement, with the intention of meeting expectations for turf function and aesthetics while simultaneously minimizing the potential for adverse environmental impact.
- Reduction of fertilizer application to the lowest possible level, in addition to the use of turf cultural practices designed to maximize efficient use of nutrients by the plants in the turf system, thereby eliminating waste and minimizing nutrient loss.
- Appropriate accounting for all nutrient inputs and record-keeping of other cultural practices that influence nutrient relations in the turf system.

Nutrient management planning must consider not only protection and enhancement of natural resources and the environment, but also sound agronomic practices that maximize the use and function of the turf. *Elements of a Nutrient Management Plan for Turf* provides the framework for the development of an effective nutrient management plan (NMP). This document can be found in Appendix C. The individual elements of a NMP are explained in greater detail in the rest of this section on soil and nutrient management.



## OBJECTIVE

**Obtain soil tests to determine the chemical and physical condition of the soil and to ascertain recommendations for adjustments.**

### Test soil to obtain needed information for sound management decisions.

- An uninformed approach to soil and nutrient management is neither economically viable nor environmentally responsible.
- Soil test results can dictate approaches for management of soil, for assessment of overall plant health, for refinement of a fertility program, for the prevention of nutrient losses to the environment, and for other aspects of management.
- Conduct **chemical** (nutrients, heavy metals, pH, CEC, exchangeable acidity, base saturation) and **physical** (texture, percent organic matter) soils analyses prior to establishment, renovation, or at the beginning of assuming management responsibility for a site where limited history is available.

Soil Chemical Properties	Soil Physical Properties
Ex. pH, fertility, nutrient reserves, heavy metals, salinity	Ex. texture, particle size distribution, percent organic matter
<ul style="list-style-type: none"> <li>• Provides information about growing conditions of soil</li> <li>• Informs additions of fertilizer and liming materials</li> </ul>	<ul style="list-style-type: none"> <li>• Provides information about behavior of soil</li> <li>• Helps in assessment of drainage characteristics and compatibility of amendments with existing soil</li> </ul>

### For established, healthy turf, conduct soil chemical analyses at least every three years and monitor pH annually.

- Have soil tested at a laboratory offering the modified Morgan extraction method for nutrients. Over fifty years of research indicates that this is the most appropriate nutrient extraction method for New England soils and is used by the University of Massachusetts Soil Testing Laboratory. Different analytical procedures can yield vastly different results.
- Test soil conditioners, topdressing materials, composts and other turf amendments separately to ensure suitability for use.

### Learn how to correctly interpret soil test results.

- Soil test results are of little value without an appropriate interpretation.
- Research data about the relationship between soil test values and the need for amendments form the foundation of soil test interpretation.
- As the soil test level for a nutrient increases, plant growth increases until a point where the nutrient is no longer limiting; this point is known as the **critical soil test level**. The critical soil test level is defined as the extractable nutrient concentration in soil above which plant growth (or performance) response to added nutrient is unlikely.
- Nutrient levels are considered sufficient when the concentration is just above the critical soil test level. This is known as the *Optimum* soil test range.

- When levels are below the *Optimum* range (*Very Low or Low*), the addition of more of the nutrient will usually improve turf performance.
- Nutrient recommendations provided by the soil testing lab are intended to meet short-term turf nutritional needs and provide enough to slowly (over several years) build soil test levels to the *Optimum* range.
- When soil test levels are in the *Optimum* range turf response to application of that nutrient is unlikely, but some amount may be recommended to maintain soil levels over time.
- It is important to keep in mind that factors other than nutrients may limit turfgrass growth, and simply adding more nutrients may not improve turf performance. To optimize turf performance and maximize response to fertilizer nutrients, sound management practices must be used (e.g., cultivar selection, establishment, irrigation management, and pest and stress management).

<b>Table 6. Interpretation of soil test categories</b>	
<b>Categories</b>	<b>Interpretation</b>
<i>Very Low</i>	<p>Soil test level is well below optimum. Very high probability of plant response to additional nutrients.</p> <p>Substantial amounts of additional nutrients required to achieve optimum growth. Fertilizer rates based on plant response and are designed to gradually increase soil nutrient levels to the optimum range over a period of several years.</p>
<i>Low</i>	<p>Soil test level is below optimum. High probability of plant response to addition of nutrients.</p> <p>Moderate amounts of additional nutrients needed to achieve optimum growth. Recommendations based on plant response and are intended to gradually increase soil nutrient levels to the optimum range.</p>
<i>Optimum</i>	<p>For most plants, low probability of response to addition of nutrient. Most desirable soil test range on economic and environmental basis.</p> <p>To maintain this range for successive years, nutrients must be retained in the system, or those nutrients removed by plants or lost to the environment must be replaced.</p>
<i>Above optimum</i>	<p>The nutrient is considered more than adequate and will not limit plant performance or quality. At the top end of this range, there is the possibility of a negative impact on the turf if nutrients are added.</p> <p>Additional nutrient applications are not recommended.</p>
<i>Excessive</i>	<p>This soil test level is independent of plant response and, due to environmental concerns, is only defined for soil test phosphorus (P). This P concentration is associated with elevated risk of P loss in leachate and runoff at concentrations high enough to impair surface water quality.</p> <p>No P should be applied and steps should be taken to minimize losses from leaching and runoff.</p>

The modified Morgan extractable nutrient values associated with each of the soil test categories for Massachusetts are summarized in Table 7. These values, derived from the results of regional soil test calibration research, are used to determine fertilizer needs for turfgrass. Notice that N is not included in Table 7. Soil testing is of limited value for determining N needs due to the dynamic behavior of soil nitrogen (N) in the humid Northeastern US. Soil testing is most useful for determining fertilizer phosphorus (P) and potassium (K) needs.

	<i>Very Low</i>	<i>Low</i>	<i>Optimum</i>	<i>Above Optimum</i>	<i>Excessive</i>
P, ppm <sup>a</sup>	0 - 1.9	2 - 3.9	4 - 14	14 - 40	>40
K, ppm	0 - 49	50 - 99	100 - 160	>160	-
Ca, ppm	0 - 499	500 - 999	1000 - 1500	>1500	-
Mg, ppm	0 - 24	25 - 49	50 - 120	>120	-
a. ppm = parts per million					

 <b>OBJECTIVE</b>	<b>Monitor soil pH regularly and manage it effectively with good liming practices.</b>
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**Monitor soil pH and maintain at a level appropriate for turfgrass species and site use.**

- Soil testing labs offer convenient and cost effective pH analysis, and provide recommendations for correcting adverse pH conditions.
- Both acid and alkaline conditions can affect nutrient availability to turfgrass plants.
- Acid conditions can increase mobility of heavy metals and pesticides.
- Many soil organisms function best when pH values are moderately acidic to near neutral.
- pH can significantly affect the composition of the turfgrass stand, and can influence incidence of many weed species.

**Know the significance of soil pH, soil acidity and buffering capacity to determine lime requirements.**

- **Soil pH** is only a measure of *active acidity*, that is, the concentration of hydrogen ions (H<sup>1+</sup>) in soil solution. Active acidity is an indicator of current soil conditions.
- There are also acidic cations (H<sup>1+</sup> and Al<sup>3+</sup>) adsorbed on soil colloids (the cation exchange capacity, or CEC) which can be released into the soil solution. This is called *exchangeable acidity*. Exchangeable acidity is much larger than active acidity.
- The most effective way to manage soil acidity is to apply agricultural limestone. The quantity of lime required is determined by the target pH (based on turfgrass species and management) and the soil's buffering capacity.

- **Buffering capacity** refers to a soil's tendency to resist changes in pH. The buffering capacity of a soil depends on factors such as the soil's clay and organic matter contents and type of clay present. Soils with a high clay and organic matter content can hold greater levels of exchangeable acidity and will require greater amounts of limestone than sandy soils lower in clay content and organic matter.

**Do not apply more than 50-70 pounds per 1000 sq. ft. (1.5 tons per acre) of limestone to established turf in a single treatment.**

- If a soil testing lab recommendation is more than this, then the limestone should be applied in several treatments on a semi-annual or annual basis until the recommended quantity of limestone is met.
- Applications in excess of 50-70 pounds per 1000 sq. ft. will not increase the rate at which pH changes, can be difficult to manage, and visibility of excessive limestone can impact turf aesthetics.
- Aeration in conjunction with lime application will help increase the effectiveness of lime and will raise pH faster.
- When preparing soil for new plantings at the time of establishment, incorporate limestone pre-plant to increase its effectiveness.

**Adjust application rates based on the calcium carbonate (CaCO<sub>3</sub>) equivalent (CCE) of the liming material being used.**

- Limestone recommendations from a soil testing lab are based on material with a 100% CCE value, however commercially available lime is never 100% pure.
- Divide the recommended limestone amount by the CCE of your liming material (usually provided on the bag):

**Example 1:**

Calcium carbonate equivalent (CCE) on the bag = 85%

Laboratory recommended limestone treatment = 50 pounds per 1000 sq. ft.

Limestone required =  $(50/85) \times 100 = 59$  pounds per 1000 sq. ft.

**Example 2:**

Calcium carbonate equivalent (CCE) on the bag = 79%

Laboratory recommended limestone treatment = 1800 pounds per acre

Limestone required =  $(1800/79) \times 100 = 2278$  pounds per acre

**Apply limestone at intervals appropriate for the soil type and drainage on the site.**

- A sandy soil needs to be limed more frequently because of its lower buffering capacity relative to a soil higher in clay and organic matter.
- A soil that is poorly drained requires less frequent liming than a well-drained soil because of the reduced leaching of alkaline soil components.

### **Account for the CCE of fertilizer materials being used.**

- As covered previously, the calcium carbonate equivalent (CCE) indicates the degree to which a material reacts to change the soil pH.
- In the case of fertilizer, CCE is defined as the amount of calcium carbonate (limestone) needed to neutralize the acidity caused by a specific amount of the fertilizer material.
- Information on CCE can be found on the fertilizer bag label.
- Some fertilizer sources (e.g. ammonium sulfate, urea, mono- and di-ammonium phosphate, superphosphate, and many composts and organic fertilizers) can cause a lowering of soil pH (positive CCE).
- Some fertilizers (e.g. poultry feather meal and poultry manure-based composts and fertilizers) can cause an increase in soil pH (negative CCE).



#### **OBJECTIVE**

**Determine the level of nutrition necessary to achieve an acceptable level of turf quality**

### **Consider the ultimate uses of the turf, and expectations of quality and performance.**

- Adequate and balanced nutrition is essential to maintaining a healthy turfgrass shoot and root system.
- Heavily used and/or intensively managed turf (for instance, athletic fields and golf course greens) often requires more nutrition than residential lawns and utility turf.
- High profile or heavily used lawns will require more nutrition than less heavily used lawns with lower quality and functional expectations.
- Adequate fertility is critical for maintaining function, managing stress, and recovering from damage.
- A dense, properly fertilized turf is more likely to capture, retain and use nutrients more efficiently than under-nourished turf.

### **Identify the grasses present on the site as well as the desirable grasses for the site and use.**

- There can be significant variation in terms of nutritional requirements between species and even among individual cultivars within species.
- Grass species and cultivars unadapted to site conditions often require additional nutrition for acceptable performance.

### **Consider the growing environment on the site.**

- Existing factors such as shade, pH, thatch, poor drainage, proximity to environmentally sensitive areas or to heat islands, and other factors can significantly modify the nutritional requirements of the turf.



### Assess the soil type and condition on the site.

- Soil type affects nutrient-holding capacity and nutrient retention characteristics.
- Sandy soils low in organic matter are prone to leaching and generally have a low nutrient reserve.
- Loamy soils with organic matter (humus) and some clay content are less prone to leaching and generally have a higher nutrient reserve. Nutrients can also bind to soil particles or organic matter and become less available.

Sandy Soils	Loamy Soils
<ul style="list-style-type: none"><li>- low nutrient reserve</li><li>- poor nutrient and moisture retention</li><li>- potential for high nutrient losses via leaching</li></ul>	<ul style="list-style-type: none"><li>- generally more fertile</li><li>- good nutrient and moisture retention</li><li>- potential for significant content of unavailable nutrients</li></ul>

### Manage soil pH appropriately.

- pH management is crucial, as pH extremes have implications for solubility (availability) of nutrients.
- pH in the slightly acidic to neutral range generally maximizes nutrient availability.
- Managing pH is often the best way to avoid micronutrient deficiencies.
- Maintaining proper pH is important for preventing build-up of unhealthy amounts of thatch.

### To maximize nutrient availability, make provisions for sufficient moisture.

- Plants take up mineral nutrients in solution, therefore adequate moisture is required for nutrient release from most fertilizers and mineralization of nutrients from organic matter.
- Less moisture makes nutrients less available to plants and less mobile in soil.
- Excess moisture, however, can facilitate nutrient loss via leaching and runoff.
- Adequate moisture is especially critical at establishment, not only for seedling growth and development, but also to enhance nutrient availability.

### Understand and encourage soil microbial activity.

- Microorganisms impact fertility by decomposing organic material, mineralizing nutrients, recycling and immobilizing nutrients and fixing and transforming nitrogen.
- Soil microorganisms are most active when soil moisture is adequate, when soil temperature is greater than 55° F, when soil is well aerated and when soil pH is near neutral (6.5-7.0).
- Microorganisms get their energy from carbon (C) sources. Like plants, they also require nitrogen (N) and can often acquire it more easily than plants.

- Microbial populations and activity can be promoted by maintaining adequate soil moisture, optimum pH, balanced fertility, good soil aeration, by limiting use of pesticides and growth regulators, and by using organic amendments with readily available C and N.
- Microorganisms will tie up N when decomposing materials with a carbon to nitrogen ratio (C:N) > 30:1. If such materials (e.g. inadequately decomposed woodchips or compost materials) are present in the soil, then additional N may need to be applied to avoid weak, stunted turfgrass growth. Preferably, soils containing such materials should not be used until the high C:N ratio components are more thoroughly decomposed.

**Understand that nitrogen (N) is the foundation of any fertility program for turf.**


- N is needed in the greatest amount because of its many effects on turfgrass growth.
- Adequate nitrogen is necessary to maintain high shoot density, realize vigorous but not excessive growth, attain healthy moderate green color (which is an indicator of the plants' potential for photosynthesis, the process by which the plant produces its energy), and the ability to recuperate from stress or pest injury.
- Excessive N can increase disease problems, reduce tolerance to high and low temperature, reduce traffic tolerance and result in moisture stress due to increased shoot growth and reduced rooting.

**Know that phosphorus is needed by turfgrass plants in amounts second only to N.**

- Phosphorus is essential when establishing new turf plantings, and also helpful in improving both rooting and winter hardiness.
- Adequate phosphorus in the seedbed is critical to rapid establishment and to reduce runoff following planting.

**Provide adequate potassium.**

- Adequate K fertility improves wear tolerance, heat and cold tolerance, stolon and rhizome growth, and rooting (thus improving water and nutrient uptake).
- Unlike N and P, K is an environmentally-benign nutrient and excess K fertilization poses little to no known risk to the health of the environment.

 <b>OBJECTIVE</b>	<b>Develop a sound plan for additions of nutrient-containing materials into the turf system; these are some of the most important and complex decisions a turf manager makes.</b>
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**Develop and implement an efficient nutrient management plan that prioritizes environmental protection:**

- Perform site analysis with identification and mapping of environmentally sensitive areas as well as areas at high risk for off-site movement of nutrients.

- Note and map specific buffer zones delineated in environmentally regulated areas such as Zone I Wellheads, wetlands and certain coastal zones, and for protection of natural resources.
- Map, including measured square footage or acreage, areas being fertilized or receiving nutrient containing materials.
- Perform and consult soil tests to determine soil water infiltration and drainage characteristics.
- Reduce applications of nutrient-containing materials to the lowest possible level required to sustain an acceptable level of turf performance.
- Implement cultural practices that maximize nutrient uptake by plants, reduce nutrient waste and minimize off-site movement of nutrients, especially by reducing soil compaction, increasing surface water infiltration, and decreasing runoff.
- Implement proper storm water management techniques aimed at reducing movement of soil and nutrients.
- Apply fertilizer and other nutrient containing materials so that they do not land or stay on hard surfaces and so that they do not enter surface waters or conduits such as catch basins that lead to surface waters.

**Understand that there is no ‘generic’ fertility program that will produce excellent turf under all conditions.**

- Factors that may vary among different fertility programs include the form of nutrients to be applied, the frequency of application, the rate of application, the timing of applications throughout the season and the placement of the fertilizer and other nutrient containing materials.
- Factors including turf quality desired, use of the turf, site conditions, grasses present, age and maturity of the turf stand, resources available, proximity to environmentally sensitive areas and other factors will influence the frequency, rate, timing and placement of applications of the particular nutrient sources to be applied.
- Select fertilizer and other nutrient containing materials appropriate for the time of year, irrigation status of the turf, and growth rate of the grasses present.
- Recognize that improper fertilization practices can be more detrimental than not fertilizing at all.
- On established turf, N and P losses from unfertilized areas can be equal to or greater than losses from fertilized areas.

**Fertilize for the right reasons.**

- Adequate and balanced nutrition is critical for healthy turfgrass shoots and roots.
- Apply fertilizer to the turf system to supply nutrients that may be in inadequate supply for the desired level of turf performance.
- Vigorously growing turf is more resistant to weeds, disease, and insect pests.
- Healthy turf provides a surface better able to withstand wear as well as mechanical and environmental stresses.
- Dense, well-rooted turf promotes water infiltration and effectively mitigates runoff.
- Good nutrition helps to promote turf with favorable aesthetic characteristics.

## Give some low maintenance turf areas special consideration in terms of fertility.

- Although turf use factors and even aesthetics are not necessarily a priority for management of many low maintenance sites, all turf requires some minimum level of fertility to provide other functional benefits such as erosion control, atmospheric carbon sequestration, slowing of runoff, and promotion of moisture infiltration.
- A soil test is the best starting point for selecting an appropriate fertilizer material and determining a reasonable rate.
- Use caution when considering fertilization for sites that have not been fertilized for several years. Certain older, low traffic and very low maintenance sites have achieved an acceptable equilibrium that may be disrupted by new fertilizer input. Unless expectations have changed or issues with growth rate or stand density are apparent, sometimes it is best to leave such sites alone in terms of fertility.

## NITROGEN

### Recognize that no soil test currently exists that can reliably inform nitrogen (N) applications to turf in the Northeast.

- There are no generic N fertilization recommendations that can be applied to all situations.
- N rates must be determined based on variables such as expected quality of the turf, use of the turf, condition of the growing environment, grass species and varieties present, and available fertilizer and nutrient containing materials.
- N should be applied at a frequency and rate that will assure vigorous growth without promoting surge growth, overstimulation or loss of N from the turf system.
- Nitrogen from all sources in the management plan should be factored into total N applied. Remember that materials including organic amendments, organic fertilizers, composts and compost derivatives, topdressings and recycled clippings can all contribute N to the turf system.

### In choosing a nitrogen **SOURCE**, carefully evaluate the readily-available nitrogen content and the slowly-available nitrogen content, as well as the specific nutrient release characteristics.

- **Water-soluble nitrogen (WSN)** is readily available to the plant.
- **Slowly-available nitrogen or slow release nitrogen (SRN)** sources include **water-insoluble nitrogen (WIN)** and various engineered slow release nitrogen technologies referred to as **controlled release nitrogen (CRN)**.
- Manufactured turf fertilizers are often formulated with a mixture of WSN and SRN.
- The percentages of WSN and SRN in a fertilizer product will affect the N release rate, price, and other factors.
- Characteristics of WSN and SRN sources may be considered either advantageous or disadvantageous depending on the specific management situation.
- Turf managers need to be especially cognizant of the release characteristics for nutrients from any material and how release rate is influenced by factors such as temperature and water.

## Water-soluble nitrogen (WSN)

Table 8 lists the most common WSN sources used by turf managers. Of these fertilizers listed, urea is the most commonly used source of N in most complete fertilizers. Calcium ammonium nitrate, ammonium sulfate, and potassium nitrate have a higher salt index and are more likely to burn the turf than urea. Mono- and diammonium phosphate are used in fertilizers when phosphorus input is also desired.

Fertilizer	Analysis (N-P-K)	Salt Index <sup>a</sup>	CaCO <sub>3</sub> <sup>b</sup> Equiv.	Lbs. Needed to Supply 1 Lb. N
Urea	46-0-0	1.7	71	2.2
Ammonium sulfate	21-0-0	3.3	110	4.8
Calcium ammonium nitrate	20-0-0	3.2	-4 <sup>c</sup>	5.0
Potassium nitrate	13-0-44	5.3	-23	7.7
Monoammonium phosphate	11-4-0	2.7	58	9.1
Diammonium phosphate	21-53-0	1.7	75	4.8

a. Relative burn potential compared to sodium nitrate. (>2.5 = high, 2.5 -1.0 = moderate, <1.0 = low)  
b. Calcium carbonate equivalent (CCE): lbs. of CaCO<sub>3</sub> (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.  
c. A negative CCE increases pH; equivalent to applying 4 lbs. CaCO<sub>3</sub> for every 100 lbs. of calcium ammonium nitrate fertilizer, or 23 lbs. CaCO<sub>3</sub> for every 100 lbs. potassium nitrate

## Water-insoluble nitrogen (WIN)

**Typical slow release N sources classified as WIN** include: ureaformaldehyde products (UF), isobutylidene diurea (IBDU), and products derived from natural organic materials such as seed meals, feather meal, activated sewage sludge, seaweed, and other plant and animal residues.

**Ureaformaldehyde (UF) fertilizers (38%N)** depend upon microbial activity to release N from complex mixtures of short, intermediate and long chain organic carbon polymers. Thus, factors which favor microbial activity will also favor N release. These conditions are: soil temperatures higher than 55°F, adequate moisture, adequate aeration, and pH between 6.0 and 7.0. UF fertilizers are less effective in late fall and early spring because of unfavorable temperatures (cold soils) for N release.

**Methyleneurea (MU) fertilizers** are similar to UF but are composed of shorter length carbon chains. MU fertilizers are less sensitive to cold temperatures compared to UF products.

**Isobutylidene diurea (IBDU, 31% N)** is a material which releases N as a result of very slow solubility in water. The physical process is essentially similar to dissolving of sugar or some other soluble product only at a much reduced rate. Finer particle size products are available for use on low cut areas or where a more rapid response is desired. Because moisture is necessary for release, IBDU is not a good choice for

non-irrigated turf areas. Conditions that are not favorable for moisture retention such as excessive thatch will be less favorable for N release from IBDU. In addition, IBDU will not release as effectively on alkaline soil with pH above 7.7. Because release is not affected by temperature, IBDU is a good choice for early spring when adequate natural rainfall is usually plentiful. IBDU is not commonly found as the nitrogen component in most complete fertilizers.

**Natural organic fertilizers** vary in composition depending upon what source of nitrogen is used. N release from natural organic fertilizers is much like that of UF fertilizer. Release depends upon microbial activity and is temperature dependent (i.e. needs warm soils). Therefore, developing a fertility program utilizing natural N sources can pose a unique challenge as N from natural organic sources will be more available during periods of warmer temperatures (when less fertility is generally needed), and less available during periods of cooler temperatures favorable for turfgrass growth. See Table 10 for information on some natural organic fertilizer materials.

### *Slow release nitrogen (SRN) technologies*

In addition to WIN sources, coated technologies are available including sulfur coated urea (SCU), polymer (plastic) coated urea (PCU) and double coated technologies (Polymer-S), which combine both sulfur and polymer coatings in the same N source. These coated technologies are SRN sources that have similar strengths and weaknesses to those exhibited by WIN fertilizers. N release from SCU can be less consistent and less efficient compared to Polymer-S and PCU sources.

**Sulfur Coated Urea (SCU, 32-36% N) and plastic coated urea (PCU)** products release N slowly because the urea pellet (prill) is covered with a coating of sulfur, plastic or both. Thus, N leaks through the pores at a slow rate compared to uncoated urea. Prills which have an incomplete or cracked coating will behave like WSN. Thinly coated prills will release N more rapidly than thickly coated prills. Adequate moisture and warm soil temperatures (warmer than 55°F) are factors favoring release of N from SCU and other coated urea fertilizer products.

Table 9 lists the most common synthetic WIN and SRN sources used by turf managers.

<b>Table 9. Characteristics of some common slow release turfgrass fertilizers.</b>				
<b>Fertilizer</b>	<b>Analysis (N-P-K)</b>	<b>Salt Index<sup>a</sup></b>	<b>CaCO<sub>3</sub> Equiv. <sup>b</sup></b>	<b>Lbs. Needed to Supply 1 Lb. N</b>
Ureaformaldehyde and Methyleneurea	38-0-0	0.3	68	2.6
Isobutylidene diurea	31-0-0	0.2	57	3.2
Sulfur coated urea	32-0-0	0.7	varies	3.1
a. Relative burn potential compared to sodium nitrate. (>2.5 = high, 2.5 -1.0 = moderate, <1.0 = low). b. Lbs. of CaCO <sub>3</sub> (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.				

**Table 10. Typical nutrient value and C:N ratio of several common organic and mineral soil amendments and nutrient containing materials.**

	Total N (%) <sup>a</sup>	C:N ratio	Fraction of organic N made available first season <sup>b</sup>	P <sub>2</sub> O <sub>5</sub> (%)	K <sub>2</sub> O (%)
<b>Plant residues</b>					
Alfalfa meal	3-4	18	0.3-0.5	0.5	2.5
Cottonseed meal	6	5	0.6-0.8	2	2
Seaweed	0	-	-	0	1
Soybean meal	7	5	0.6-0.8	2	2
Corn gluten meal <sup>c</sup>	9	4	0.6-0.8	0	0
<b>Animal products</b>					
Dried blood	12	3	0.7-0.9	1	0.5
Bone meal (steamed)	3	4	0.5-0.7	15	0
Feather meal	13	4	0.7-0.9	0	0
Fish emulsion	4	3	0.7-0.9	2	0
Fish meal	9-12	4	0.7-0.9	7	0
Poultry litter <sup>d</sup>	3-4	15	0.4-0.6	3	3
<b>Compost (mature)<sup>d</sup></b>					
Manure	1.5-2	20-25	0.1-0.15	2	1
Yard waste	0.5-1	20-25	0.1-0.2	1	1
<b>Mineral materials</b>					
Potassium sulfate	0	-	-	0	50
Sul-Po-Mag	0	-	-	0	21
Wood ash	0	-	-	1	10
Colloidal rock phosphate <sup>e</sup>	0	-	-	25 <sup>f</sup>	0
Rock phosphate <sup>e</sup>	0	-	-	20-32 <sup>f</sup>	0
Granite dust <sup>e</sup>	0	-	-	0	3-5 <sup>f</sup>
Greensand <sup>e</sup>	0	-	-	1 <sup>f</sup>	4-9 <sup>f</sup>

- a. Nutrient concentration of organic materials is inherently variable. Estimated values are provided for reference only. It is best to have materials tested in order to determine appropriate application rates.
- b. To estimate the quantity of total N expected to become plant available in the first season following application, multiply by the appropriate coefficient.
- c. Corn gluten meal inhibits germination of some small seed plants and has been promoted as a natural pre-emergent herbicide. Avoid using where turfgrass has been recently seeded or where overseeding is imminent.
- d. Compost and poultry litter also contain varying quantities of NH<sub>4</sub>, which is immediately plant available; however, NH<sub>4</sub> is subject to volatilization losses if material is not immediately incorporated.
- e. Relative nutrient availability of nutrients from rock powders varies with origin of material, soil pH, and depends largely on fineness of grind.
- f. These values represent total K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub>. These materials are extremely insoluble therefore available K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> from these materials will be much lower.

**Use slowly-available SRN along with readily-available WSN for fertilizer applications, especially on sandy soils prone to leaching.**

- WSN and SRN sources each contribute both positive and negative properties to a fertilizer product. A balance of both WSN (fast) and SRN (slow) types are preferred for most turf applications.
- As a general rule, during periods of peak shoot growth typical of spring and fall it is desirable to have not less than 25 percent of the total N in the fertilizer derived from some SRN source. The fertilizer should also contain a sufficient amount of WSN to support active growth especially during favorable shoot and root growth periods of spring and fall.
- If fertilization is necessary during periods of minimal growth typical of summer stress, it is advisable to have not less than 50 percent of the total N (though not less than 75% is preferable) in the fertilizer derived from an SRN source (WIN or CRN).

<b>Characteristics of readily-available (WSN) N sources:</b>	<b>Characteristics of slowly-available (SRN) N sources:</b>
<ul style="list-style-type: none"> <li>- provide a rapid increase in both color and growth rate</li> <li>- release of N is relatively independent of temperature, so can be used throughout most of the growing season with acceptable response</li> <li>- relatively rapid plant response rate</li> <li>- relatively short period of plant response (residual of 4 to 6 weeks at normal rates)</li> <li>- potential for surge shoot growth</li> <li>- can be applied in either granular or liquid form</li> <li>- high foliar burn potential (salt index) when applied at excessive rates or during periods of high temperature</li> <li>- greater potential for loss via leaching or volatility (gaseous losses)</li> <li>- generally less expensive per unit N when compared to many SRN sources</li> </ul>	<ul style="list-style-type: none"> <li>- release N slowly over a longer period of time than readily-available N sources</li> <li>- some sources are temperature dependent and do not release N in cold soils (&lt; 55 °F)</li> <li>- in moist, warm summers nutrient release may be more rapid</li> <li>- low potential for foliar burn (salt index)</li> <li>- do not result in flushes of rapid growth (surge growth)</li> <li>- provide a longer residual plant response</li> <li>- potential carryover of N into the following growing season(s)</li> <li>- lower potential for gaseous loss and loss via leaching</li> <li>- relatively slow color response</li> <li>- generally cost more per unit of N when compared to WSN sources</li> </ul>

**When using natural organic sources of N, take care not to over apply phosphorus.**

- Soil testing is the first step before applying any P containing fertilizers or P containing materials.
- Since almost all natural organic nitrogen sources contain P, care should be taken that excess P is not applied in an attempt to supply adequate N.



- Organic N sources exhibit a low N content by weight of fertilizer. The total fertilizer amount needed to meet the turf system N requirement increases with decreasing N content of the N source. This in turn may lead to over-application of P in a turf system, especially when soil test P is sufficient for turf growth.
- Repeated applications of organic N sources that contain P can continue to overload the turf system with unnecessary P over time.
- Where organic fertility programs are being implemented and soil test results show *Above Optimum* levels of P, the addition of P containing fertilizer, amendment, topdressing or other materials should be avoided.

See Table 10 for information on natural organic fertility sources.

### **Exercise particular care in determining an appropriate *RATE* of fertilizer N.**

- As discussed previously, turfgrasses are highly responsive to fertilizer N. N is also a nutrient that can impair ground and surface water in the event of undesired migration out of the turf system.
- The term ‘fertilization rate’ can refer either to the rate of an individual application or to the amount of fertilizer nutrient applied on an annual basis, taking into account all sources of N.
- The N fertilization rate depends upon many factors such as: N source to be applied, time of the year, fertility requirement of the species and cultivars present, specific management goals (for example, successful overseeding or repairs), and expectations for quality and performance.
- Turf that is intensively used (e.g. sports fields, golf courses) may need special considerations in terms of appropriate N rates. The N rate may need regular adjustments to provide for adequate growth and recovery at specific times of the year.
- Any practice that promotes rooting activity especially into deeper portions of the soil profile will increase acquisition of both water and nutrients by the turf system. To that end, keeping N to its lowest possible level needed to maintain optimum turf function will promote greater rooting relative to shoot growth (high root-to-shoot ratio) and increase nutrient and water use efficiency.

Current fertilizer guidelines may call for as much as 4 lbs. N per 1000 sq. feet per season for the turfgrass species present on a site. Guidelines for N input to turf are exactly that: guidelines. If turf of acceptable quality can be maintained at a rate lower than 4 lbs. N per 1000 sq. feet per season, then reducing the rate is justified and helps to reduce labor, fertilizer cost, and the potential for excess nutrients in the system.

Lower N rates may be possible where:

- fertile loam soils are present
- traffic is not intensive
- higher height of cut is practiced
- grass clippings are returned
- turf is under shade
- turf is not irrigated
- turf is older and well-established

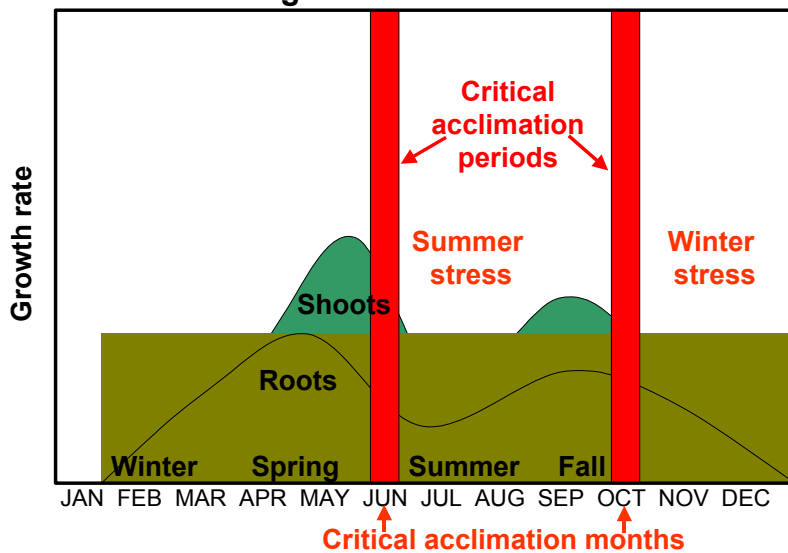
**Table 11. Typical nitrogen fertilizer rate ranges for common cool-season lawn grasses.**

	Kentucky bluegrass	Perennial ryegrass	Tall fescue	Fine fescues
Fertility level	med - high	med - high	med - high	low - med
Lbs. N per 1000 sq ft per season	2 - 4	2 - 4	2 - 4	0 - 2

**Determine the *FREQUENCY* of fertilizer applications based on the nitrogen characteristics of the fertilizer material.**

- Fertilization programs for lawns may vary from 1 to 4 or more applications per season, depending on several factors, including the nutrient release characteristics of the material used.
- Fertilization programs utilizing only WSN are not suggested for lawns.
- Multiple, frequent applications of very small rates (0.1 to 0.2 lbs. of N per 1000 sq. feet per application of WSN sources, referred to as spoon-feeding) are sometimes utilized on heavily used, high value turf (e.g. sports fields and golf course tees and greens) where rapid and complete uptake of fertilizer nutrients is important for controlled plant growth and recovery, and where the presence of well drained soils requires strategies to reduce leaching potential. Such labor intensive spoon-feeding programs are seldom appropriate for lawn turf.
- The proportion of SRN in a fertilizer should be increased during the pre-stress period approaching the summer (i.e. June) or during the summer to protect against foliar burn and surge growth. Similarly, for intensively used turf such as sports turf, more SRN in a fertilizer is needed in mid-fall during the pre-stress period preceding low temperatures when plants are acclimating (conditioning) to cold stress. It is extremely important to keep WSN as low as possible during these pre-stress periods.

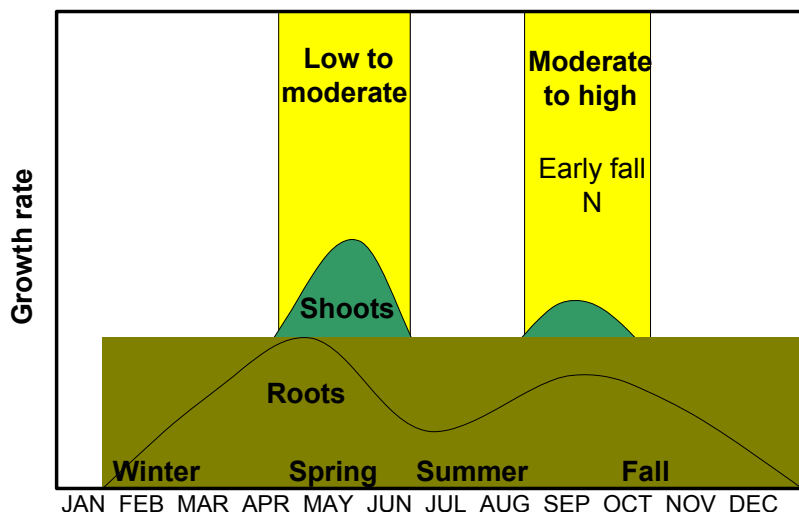
**Preconditioning Periods in Cool-Season Grasses**



**TIME fertilizer applications so that maximum nitrogen availability corresponds with periods of active turfgrass growth.**

- An N application during late spring (approximately Memorial Day) is widely practiced in order to enhance quality going into summer and to encourage growth before the high temperatures and moisture stress of summer occur. It is important that such an application does not stimulate the turf into growth during the stressful summer months (especially if irrigation is not available). Fertilizer applied at this time should contain a high percentage of SRN (minimum of 50% or more).
- Fertilization during July and August should be approached cautiously in order to avoid excess growth during periods of high temperature and moisture stress. If fertilization during the summer is necessary, it is recommended to have not less than 50 percent of the total N as SRN, though not less than 75% of total N as SRN is preferable.
- Application of fertilizer materials should be avoided on non-irrigated turf in summer and during times of high temperature stress or moisture stress. More flexibility is possible on irrigated sites.
- **The late August/early September (approximately Labor Day) fertilization period is the most important for cool season grasses.** Recovery from summer stress injury as well as increased shoot growth from tillering and rhizome production are enhanced by sufficient N availability throughout the fall.
- Some sophisticated management programs employ what is referred to as a late season (or late fall) fertilizer application. The proper approach for late season fertilization is to apply after the last mowing after shoot growth has stopped but before the turf has lost green color.
  - The correct timing of late season fertilization, which can vary considerably from year to year depending on prevailing conditions, is extremely critical in order to realize positive benefits. Incorrect timing can stimulate turf into undesirable growth immediately prior to the onset of low temperature stress, and/or increase the potential for nutrients to move off-site due to leaching or runoff.
  - Because of the delicate nature of late season fertilization, it is more appropriate for specific management objectives on intensively-used, high value turf areas (e.g. sports fields and golf courses). Late season fertilization is normally not warranted for less intensively managed sites.
  - The success of late season fertilization is dependent on proper late summer-early fall fertilization.
  - Late season fertilization is best practiced by an experienced turf manager.
  - **Late season fertilization should be avoided in areas that are or may be environmentally sensitive.**
- Some programs also employ an early spring application of N. This application is used primarily to enhance quality and early spring growth at the time when preemergence weed control materials are being applied. This application is also used to stimulate growth and enhance recovery of high-use turf (e.g. baseball and soccer fields and parks).
- Do not apply fertilizer or other nutrient containing materials to drought dormant, cold dormant, inactive or otherwise brown turf. Do not apply fertilizer to frozen ground.

## Periods of Peak Nitrogen Use: Cool-Season Grass



**Table 12. Suggested options for timing, rate, and % SRN<sup>a</sup> for N applications<sup>b</sup> based on number of applications per year (lbs N/M = lbs of nitrogen per 1000 square feet).**

Time of year	Number of N applications				
	1x/yr	2x/yr	3x/yr	4x/yr <sup>c</sup>	4x/yr <sup>c</sup>
Spring (after ~50% green-up)		50-100% SRN 1.0 - 1.5 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M	
Late spring/ early summer			50-75% SRN 0.75 - 1.0 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M
Summer (irrigated turf only)				50-75% SRN 0.75 - 1.0 lbs N/M	50-75% SRN 0.75 - 1.0 lbs N/M
Late summer/ early fall (~Labor Day)	75-100% SRN 1.0-2.0 lbs N/M	50-100% SRN 1.0 - 1.5 lbs N/M	25-50% SRN 1.0 - 1.5 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M	25-50% SRN 0.75 - 1.0 lbs N/M
Late fall (late season) <sup>d</sup>					25-50% SRN 0.75 - 1.0 lbs N/M
<b>TOTAL ANNUAL N</b>	<b>1.0 - 2.0 lbs N/M</b>	<b>2.0 - 3.0 lbs N/M</b>	<b>2.5 - 3.5 lbs N/M</b>	<b>3.0 - 4.0 lbs N/M</b>	<b>3.0 - 4.0 lbs N/M</b>

- Ranges for slow-release nitrogen (% SRN) content are approximate guidelines. Specific SRN percentages may vary from commercially available products by as much as 5% (plus or minus). Use higher SRN content when available, and especially on sandy root zones or during stress and pre-stress periods.
- Specific N rates may vary based on several factors including turfgrasses present, management, and turf use. For predominately fine fescue turf or shaded sites use lower listed N rates.
- Programs utilizing 4 or more N applications per year are best suited for intensively used, high-value turf.
- Final application made after last mowing while grass is still green. *As noted in the text, not necessary for most lawns and not appropriate for environmentally sensitive sites.*

## PHOSPHORUS AND POTASSIUM

### Supply phosphorus and potassium based on soil test results.

- Soil testing is the most accurate method for determining P and K fertilizer requirements.
- Phosphorus and potassium are expressed in their respective oxide forms, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, for the purposes of fertilizer grades and recommendations.

### Understand that special considerations are necessary for application of phosphorus-containing materials.

- For mature turf, phosphorus application is rarely needed on most soils unless a deficiency is indicated by a soil test.
- When soil tests indicate P is needed, use rapidly-available sources of P for new seedings to ensure adequate levels of soluble phosphorus for young grass shoots. Note that some organically approved mineral sources of P may not release available phosphorus quickly enough for rapid turfgrass development (e.g., rock phosphate, colloidal soft rock phosphate).
- When soil test phosphorus levels for established turf are below optimum (*Very low* or *Low*; see Table 6, 'Interpretation of soil test categories'), the recommended application rate for P is intended to meet immediate turf phosphorus needs in addition to gradually raising soil test levels into the *Optimum* range (see Table 14, 'UMass soil test phosphorus application guidelines').
- Applying P in conjunction with cultivation (aeration, dethatching, etc) will facilitate incorporation into the root zone and reduce the potential for phosphorus loss.
- When soil test phosphorus levels are in the *Optimum* range **very little, if any**, P is needed for established turf.
- When soil test phosphorus levels are *Above Optimum*, **no** P is needed for establishment or maintenance.

Fertilizer	Analysis	Salt Index <sup>a</sup>	CaCO <sub>3</sub> Equivalent <sup>b</sup>	Lbs. needed to supply 1 lb. P <sub>2</sub> O <sub>5</sub>
Mono-ammonium phosphate	11-52-0	2.7	58	1.9 (also supplies 0.2 lbs. N)
Di-ammonium phosphate	18-46-0	1.7	75	2.2 (also supplies 0.4 lbs. N)
Super-phosphate	0-20-0	0.4	0	5.0
a. Relative burn potential compared to sodium nitrate. (>2.5 = high, 2.5 -1.0 = moderate, <1.0 = low) b. Lbs. of CaCO <sub>3</sub> (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.				

Table 14. UMass soil test phosphorus application guidelines.				
	Soil test phosphorus level			
	<i>Very low</i>	<i>Low</i>	<i>Optimum</i>	<i>Above Optimum</i>
	lbs P <sub>2</sub> O <sub>5</sub> / 1000 sf / year			
<b>Turf Establishment</b>	2.0 – 2.5	1.0 – 2.0	0.5 – 1.0	0
<b>Turf Maintenance</b>	1.5 – 2.0	0.5 – 1.5	0 – 0.5	0

**Limit P input to the lowest possible level needed to achieve adequate turf quality and prevent deficiency.**

- Soil test phosphorus levels should not exceed the environmental critical concentration (40 ppm Modified Morgan extractable P) in order to protect surface water quality. When extractable phosphorus exceeds the environmental critical concentration, the risk of dissolved phosphorus loss in subsurface water flow or runoff in amounts that pollute surface water is significantly increased. As with N, the potential for leaching of P is greater on sandy root zones.
- To avoid phosphorus overload in the turf system, nutrients from all sources in the management plan should be factored into total P applied. Organic amendments, retained clippings and many compost materials can contribute P into the turf system.
- Where soil test phosphorus levels are *Excessive* (greater than 40 ppm P), **no P containing materials should be applied** and active steps should be taken to minimize surface runoff from the site.
- **Natural organic sources of P, whether approved in organic programs or not, do not pose a lower risk to water resources than synthetic fertilizer P.** Where organic fertility programs are being implemented and soil test results indicate *Above Optimum* levels of P, the addition of P containing fertilizer, soil amendments or topdressing materials should be avoided.

See Table 10 for a listing of natural organic nutrient sources containing P.

**Apply potassium in accordance with soil test results and management goals**

- When soil test K levels are below *Optimum* (*Very low* or *Low*), application of K fertilizer will generally improve turf health. Even when soil test K levels are in the *Optimum* range, turf health may benefit from a modest application of K. See Table 6, 'Interpretation of soil test categories'.
- While every fertilizer application may not include K, those applications preceding stress periods are good times to supplement K and to correct for soil K deficiencies.
- Where no P is needed, apply N and K over the growing season following a ratio of approximately 3-0-2 or 4-0-2.
- Early fall applications in particular are often made with a fertilizer containing N and K to improve winter survival without over-stimulating growth.

Potassium chloride (KCl) is the most common K source used in turf fertilizers because of its lower cost and moderate burn potential (Table 10). Potassium sulfate (K<sub>2</sub>SO<sub>4</sub>) is used in high-grade turf fertilizers because of its low burn potential (low salt index).

Fertilizer	Analysis	Salt Index <sup>a</sup>	CaCO <sub>3</sub> Equivalent <sup>b</sup>	Lbs. needed to supply 1 lb. K <sub>2</sub> O
Muriate of potash (KCl)	0-0-60	1.9	0	1.7
Sulfate of potash (K <sub>2</sub> SO <sub>4</sub> )	0-0-50	0.9	0	2.0
Potassium nitrate (KNO <sub>3</sub> )	13-0-44	5.3	- 23	2.3

a. Relative burn potential compared to sodium nitrate. (>2.5 = high, 2.5 -1.0 = moderate, <1.0 = low)  
b. Lbs. of CaCO<sub>3</sub> (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.

	Soil test potassium level			
	<i>Very low</i>	<i>Low</i>	<i>Optimum</i>	<i>Above Optimum</i>
<b>Management level</b>	lbs K <sub>2</sub> O / 1000 sf / year			
<b>Normal</b>	3 – 4	2 – 3	1 – 2	0
<b>Intensive <sup>a</sup></b>	4 – 5	2 – 4	1 – 2	0

a. Use intensive recommendations for heavily used or intensively managed turf such as sports turf, or golf greens and tees.

See Table 10 for a listing of natural organic nutrient sources containing K.



## OBJECTIVE

**Employ cultural management practices that maximize nutrient uptake by plants, reduce nutrient waste and minimize off-site movement of nutrients.**

Fertilization and supplemental irrigation are important in many turf management scenarios for the maintenance of an acceptable level of turf performance. Water, in particular, is an especially important consideration for effective nutrient management. Adequate moisture is critical for efficient uptake and use of nutrients, while excess moisture can lead to undesirable movement of nutrients in the environment. To protect precious environmental resources and to minimize maintenance costs, water and fertilizer inputs need to be kept to their lowest possible levels. This lower input can be accomplished in part by eliminating wasteful use and taking action to promote the retention of water and nutrients within the plant-soil system. Furthermore, by eliminating waste the turf practitioner can help to minimize the potential impact of nutrients such as phosphorus and nitrogen on surface and ground water quality. This can be done by enhancing the ability of turfgrass plants to acquire water and nutrients or equivalently, improving the nitrogen use efficiency (NUE) and water use efficiency (WUE) of the turfgrass system. Increased NUE and WUE helps to sustain greater turf quality and function under reduced water and fertilizer input.

Although NUE does not directly account for relationships involving other essential plant nutrients (such as P and K), NUE is an effective metric for evaluating the efficiency of various plant nutrients within a turf system. Remember that N forms the foundation of any fertility program for turf, therefore steps to improve N use efficiency by optimizing inputs and reducing waste will in turn promote efficient use and retention of other essential nutrients.

### **Correct factors that reduce soil infiltration and promote runoff.**

- Low soil infiltration rates promote runoff and therefore may increase reliance on costly supplemental fertilization and irrigation. Whether the source of water is rainfall or irrigation, increasing the soil infiltration rate will reduce runoff potential, protect resources and promote turf quality.
- It is important to alleviate any condition or practice that reduces soil infiltration and promotes runoff:
  - **Manage excessive thatch and reduce soil compaction:** Thatch can be hydrophobic in summer, which can result in low soil infiltration rates. Compaction increases soil hardness and inherently reduces soil infiltration rates. These factors together inhibit rooting depth and density. These same conditions also promote surface water runoff as well as nutrient and pesticide losses, conditions that reduce plant and irrigation efficiency and compromise environmental quality.
  - **Do not irrigate in excess of the soil's capacity to absorb water:** Where slow infiltration is problematic, multiple cycling of irrigation may be necessary to prevent runoff.



- **Water in fertilizer and nutrient containing materials immediately after application to move nutrients to the root zone, where they can be absorbed by the plant:** Time fertilizer applications on un-irrigated lawns to coincide with subsequent rainfall whenever possible, avoiding applications prior to forecast periods of extended or excessive rainfall. Fertilize or apply nutrient containing materials in conjunction with core aeration whenever possible to further promote incorporation of fertilizers into the root zone.
- **Protect steep slopes at establishment through use of mulches, netting or other appropriate material:** If steep grades are unavoidable, then it is likely that multiple cycling of irrigation will be needed in such areas to prevent runoff.
- **Employ appropriate cultural practices to maintain turf density:** Decreasing shoot biomass translates to reduced capacity to inhibit water runoff.
- **Manage heavy traffic:** Turf thinning and soil compaction increase relative to the amount of traffic on the turf.
- **Select and introduce turfgrass species and cultivars adapted for the site and use:** Carefully selected, well-adapted species and cultivars have greater capacity to maintain turf function, shoot density and extensive rooting with less maintenance input in terms of fertilizer and water. Poorly adapted plants will be challenged to maintain shoot density sufficient to minimize runoff.
- **Avoid excessive soil firming during establishment.**
- **Provide proper soil preparation at planting to minimize stones and debris at the soil surface.**

### Minimize leaching loss of water and nutrients.

- Soil water that moves below the rooting profile is water unavailable for plant uptake; such leaching loss is wasteful.
- Leaching events also move nutrients such as N and P below the root zone and out of the turfgrass system, which increases the potential for adverse environmental impact.

Alleviate factors that can lead to leaching of water and nutrient inputs:

- **Avoid exceeding turfgrass evapotranspiration (ET) rates in summer:** Irrigating deeply and infrequently according to ET replacement will help to prevent leaching loss.
- **Avoid the use of highly water soluble N (WSN) fertilizers in summer:** Use of slowly-available N (SRN) instead minimizes the potential for nutrient loss, especially on sandy soils that are prone to leaching. Fertilizer with at least 50% of total N as SRN is preferred (75% as SRN is better). Frequent 'spoon feeding' or foliar N at very low WSN rates may be appropriate for more sophisticated systems.
- **Maintain turf density:** Thin turf has less photosynthetic leaf area to support sufficient root mass to enable effective uptake and utilization of water and nutrients.
- **Do not apply fertilizers to dormant or inactive turf:** Minimal shoot and root activity compromise uptake and utilization of water and nutrients.

## Eliminate waste.

- Promptly correct any practice that may result in removal or loss of nitrogen or water from the turf system.

Alleviate factors by that contribute to waste:

- **Retain grass clippings whenever possible:** Significant nitrogen and phosphorus is removed from turf systems by clipping removal, therefore the return of clippings to retain nutrients in the turf system is preferable in the vast majority of cases. When retaining clippings, supplemental fertilization must be adjusted to avoid possible overloads of N and P. Exceptions for removal of clippings include when they are excessive and may smother turf, when certain diseases are present, or during seed head formation of weed species. If clippings must be removed, dispose of them properly to avoid undesirable release and movement of nutrients as the clippings decompose.
- **Direct applications of water and fertilizer to turf areas:** Water and fertilizer that reach non-grassy areas and hard surfaces are not useful to turf and may be rapidly conveyed off-site, dramatically increasing the potential for negative environmental impact. Promptly clean up fertilizer as well as pesticide materials and turfgrass clippings that settle on impervious surfaces. Also, fertilizer and other nutrient containing materials should not be used as de-icers. Where irrigation is provided, water should only be applied to turf, not hard surfaces, and at a rate that ensures adequate infiltration.
- **Properly calibrate fertilizer and irrigation delivery equipment:** Irrigation audits and spreader calibration should be conducted regularly, consistently and correctly.
- **Manage weeds:** Undesirable grassy and broadleaf weeds compete with desirable turfgrasses for water and nutrients, therefore weed control/removal is important for improving efficient use of nutrients and water.
- **Prevent nutrient deficiencies:** Under-fertilized turf is less capable of mitigating losses of water and nutrients through leaching and runoff. Insufficient phosphorus (P) and potassium (K) may reduce NUE and WUE especially if rooting is inhibited. Furthermore, P should only be applied based on soil test results and soil testing for K is advisable as well.

## Condition plants for nutrient uptake with responsible and effective cultural practices.

- Any practice that promotes rooting activity, especially in the deepest portions of the soil profile, will increase acquisition of both nutrients and water by turfgrass plants.

Alleviate factors that reduce turf system NUE and WUE by inhibiting rooting depth and density:

- **Keep N inputs to the lowest possible level:** This will promote greater rooting relative to shoot growth (high root-to-shoot ratio) and increase both NUE and WUE of turf.

- **Manage excessive thatch and relieve soil compaction:** These factors are inhibitory to rooting depth and density. These same conditions also promote surface water runoff as well as nutrient and pesticide losses, conditions that reduce plant and irrigation efficiency.
- **Avoid excess levels of WSN and close height of cut:** These practices in combination are more detrimental to rooting depth than either practice considered alone. SRN is more effective in increasing turf NUE and WUE compared to WSN (for example, a minimum of 75% of total N as SRN in summer is highly effective in minimizing shoot growth and alleviating root stress). Cutting too low, or too frequently, shrinks leaf area which translates into reduced photosynthetic capacity. Less photosynthetic capacity in turn can support less root mass and depth.
- **Do not over-irrigate:** Maintaining root zones at field capacity by over-watering will inhibit rooting, decrease drought resistance, and promote disease and soil compaction. Furthermore, excess moisture in the root zone can limit soil oxygen and affect active uptake of nutrients. Use of wilt-based irrigation (irrigation withheld until the onset of mild moisture stress) with ET replacement will promote rooting and root activity and prevent leaching of water and nitrate-N. Wilt-based irrigation with ET replacement is very effective in enhancing NUE and WUE of turf.
- **Manage soil pH:** Acid soils (pH < 5.5) can inhibit rooting. Furthermore, availability of nutrients such as iron and manganese can reach toxic levels when pH is low. Follow soil test recommendations for adjusting soil pH to the slightly acidic to neutral range (6 to 7).
- **Avoid shallow rooted species and cultivars:** Plants with genetically limited rooting potential exhibit poor drought resistance as well as poor NUE and WUE. Generally plants with superior drought resistance have greater NUE. Use National Turfgrass Evaluation Program data (NTEP, <http://www.ntep.org>) for selecting drought hardy turfgrasses. See Section 4, *Turfgrass Selection*, in this publication, for more information on considerations in the selection of turfgrasses.
- **Take care with applications of soil applied preemergence herbicides:** Some soil applied preemergence herbicides can negatively affect rooting of desirable turfgrasses. When a need for these type of materials has been identified as critical to the proper functioning of the turf, use a split application in spring to control weedy summer annuals such as crabgrass in two applications at reduced rates. Consult pesticide labels for split application rates that may be less detrimental to rooting without sacrificing season long weed control.



## OBJECTIVE

**Establish new turf areas quickly and effectively while protecting soil and nutrients from loss.**

### **Plant during favorable periods that promote rapid establishment.**

- The ideal period for establishment in the Northeast is late summer to early fall.
- Consider using grasses that establish quickly, such as perennial ryegrass, to promote rapid grass cover when needed. This is especially important on slopes or in environmentally sensitive areas to minimize soil loss and potential environmental contamination.
- Avoid excess firming of soil.

### **Take steps to prevent movement of soil off-site.**

- Eliminate potential for storm water runoff; keep soil from running onto hard surfaces or into catch basins.
- Consider sodding areas that have a high erosion potential during the establishment phase. Sod should only be installed if irrigation is available throughout the establishment phase.
- Take all available steps to maximize turfgrass germination and rapid establishment. Mature turf has a much greater capacity to hold soil in place and prevent erosion.

### **Promote rapid establishment with mulches and similar materials.**

- Consider using mulches or erosion control blankets to promote soil infiltration of water, to reduce soil loss, to buffer temperature fluctuations and to hasten germination.

### **Promote rapid establishment with proper fertility.**

- Proper fertility at establishment greatly reduces the potential nutrient losses over time.
- Phosphorus (P) needs by the turfgrass plant and rates of P fertilization are greatest during the establishment period. Apply P as recommended by a soil test.
- N and P losses can be greater at establishment due to low shoot density, use of readily-available nutrient sources, and high irrigation frequency. Therefore, providing conditions for rapid establishment and protecting soil from loss are critical.



## OBJECTIVE

**Keep application records for fertilizer and nutrient-containing materials.**

**Maintain detailed application records as a useful tool for evaluating and adjusting the fertility program.**

- Good records are invaluable for evaluating the performance of an existing fertility program, as a guide when making adjustments, and as a reference from season to season.

**The following information is suggested for fertility records:**

- Application location
  - Presence of and distance to surface water, wellheads or other environmentally sensitive areas
  - Soil-type
  - Date of most recent soil test
  - Product or material applied
  - Nutrient analysis of material
  - % slowly-available N (SRN as WIN or CRN)
  - Amount of material used and timing
  - Application equipment used (drop, rotary, spray)
  - Application rates used for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O
  - Wind speed at application
  - Rainfall amounts 24 to 48 hours before/after application
  - Magnitude and length of slope of fertilized area
  - Total annual N used
  - Total annual P used
  - Total annual K used
  - Other comments/notes
-

## SECTION 8

### MOWING

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 <b>OBJECTIVE</b>	<b>Mow so as to maintain the health and competitive ability of the turf while providing acceptable quality and performance.</b>
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**Acknowledge that mowing is the most basic and integral cultural practice employed in the management of turf.**

- Mowing height and mowing frequency directly influence several stand characteristics such as leaf area, shoot density, and shoot/root ratio.
- Regular mowing is a key deterrent of many weed species.

**Mow at the higher end of the acceptable mowing height range for the turfgrass species, growing conditions, site and use.**

- Each species and specific cultivar within a species has an optimum mowing height range that can vary depending upon site characteristics, turf use, and environmental conditions.
- Most lawns of cool season turfgrass species (Kentucky bluegrass, perennial ryegrass, the fine fescues and tall fescue) should be mown in the range of 2½ to 3½ inches, unless specific cultivar selections have been made for adaptation to lower mowing heights.
- Mowing too low reduces the amount of leaf area available for photosynthesis which in turn may reduce plant vigor.
- The root systems of grasses generally become shorter and less prolific as cutting height decreases, resulting in a need for more frequent watering and fertilization to compensate for diminished capacity to obtain water and nutrients from the soil.
- As cutting height is reduced, lawns become less tolerant of environmental stresses and more prone to invasion by weeds than lawns maintained at a higher cutting height.
- Mowing too high, beyond the higher end of the mowing height range, often results in undesirable reductions in stand density.

**Know that the growth rate of a lawn dictates the necessary mowing frequency.**

- Factors that affect turfgrass growth rate include turfgrass species composition, day length, temperature, moisture availability and soil fertility (especially nitrogen).

- Follow the '1/3 Rule' - no more than one third of the existing shoot growth should be removed at any one mowing to avoid undue stress on the turf.

**Example:** if a lawn is being mown at 2½ inches, it should not be allowed to grow higher than about 3½ inches before the next mowing.

- If a lawn grows excessively high, the mowing height should be gradually reduced to the proper height over a span of several mowings rather than all at once.
- Mowing frequency is reduced during drought or other stress.
- Mow into the fall until turfgrasses stop growing.



*Mow at an appropriate height for the species and turf use, and mow frequently enough to observe the '1/3 Rule'.*

### **Vary mowing patterns whenever possible.**

- Varying the mowing pattern helps to avoid areas of compaction and subsequent poor turf growth.
- The direction of mowing should be varied with each mowing in order to promote upright shoot growth.
- The incidence of a horizontal growth orientation (known as grain) can be minimized if the lawn is mown at right angles on alternate mowings.

## Manage clippings responsibly.

- Clippings should be recycled into turf canopy whenever possible. Returned clippings result in the retention of valuable nitrogen and other nutrients in the turfgrass system.
- Returned clippings may help to improve the status of the soil over time, especially if it is sandy and/or low in organic matter.
- Returned clippings do not normally contribute to increased thatch formation. Clippings are composed primarily of easily degradable compounds which break down rapidly and do not accumulate.
- Consider the use of mulching mowers, rotary mowers which cut the clippings into small, fine pieces, allowing the clippings to fall down into the turf canopy more easily and to decompose more quickly.
- Remove clippings during primary seed production time for weed species that spread via new seedlings (e.g. crabgrass or annual bluegrass), to reduce disease potential (e.g. when pressure or presence of damaging diseases is high), or to eliminate potential smothering of turfgrass plants from excessive clipping volume.
- Mow when the lawn is dry and at a proper frequency to prevent unsightly clumping of clippings.
- Clippings that reach or accumulate on impervious surfaces should be cleaned up promptly, as clippings left in such areas can be carried with runoff and contribute to nutrient loading in ground or surface water.
- Dispose of clippings in an environmentally sustainable manner. Clippings should be composted and reused as finished compost in the landscape whenever appropriate.
- Clippings that may contain pesticide residues, even when composted, should not be used in gardens intended for food production.
- Comply with pertinent composting regulations and ordinances.



*Recycle clippings into the turf canopy whenever possible. Clippings that land on hard surfaces should be cleaned up promptly to reduce the potential for environmental impact.*



**Choose mowing equipment appropriate for the site with consideration for optimum performance, lowest energy use and reduced emissions.**

- **Reel mowers** employ a rotating cylinder of blades (usually five or six) which catch the grass against a stationary bedknife in order to cut it. While reel mowers provide the finest quality of cut available, they are expensive, some are not easily adjusted, and require specialized equipment for sharpening. Also, they cannot be used where stones, twigs, or other debris may be present because of potential damage to the cutting units. For these reasons reel mowers are generally restricted to fine turf areas such as golf courses and high maintenance athletic fields. Manual single-reel rotary mowers may be appropriate for some small turf areas with flat grades.
- **Rotary mowers** employ a horizontally rotating single blade and are by far the most commonly used mower for home lawns. Rotary mowers cut the grass by impact (similar to how a machete works) and thus cause a rougher, more uneven cut than a reel mower. However, rotary mowers do an acceptable job on virtually any lawn and are much easier to maintain than reel mowers.
- Select mowers that provide the necessary level of performance, while using the least amount of energy and producing the least amount of greenhouse gas emissions.

**Keep mowers maintained and blades sharpened.**

- The value of sharp mowing blades cannot be over-emphasized. It is critical to keep mower blades as sharp as possible regardless of which type of mower is chosen.
  - Dull mowers tear the grass blades rather than cut them. This can result in excessive injury to the plants as well as a brownish cast to the turf.
  - Mower blade injury can cause several adverse effects, including increased turfgrass water use and the promotion of disease infection.
-

## SECTION 9

# TRAFFIC STRESS & TURF CULTIVATION

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### OBJECTIVE

**For long-term performance, take steps to reduce traffic stress on turf areas.**

#### **Understand that traffic results in wear and compaction stress.**

- Effects from both vehicular and foot traffic are a primary cause of injury to the shoots and foliage of turfgrass plants.
- Wear damage is immediate and involves bruising and crushing injury to turfgrass shoots.
- Compaction refers to stress caused by increases in soil hardness. Compaction is chronic and develops over time at the root zone level.
- Traffic stress (both wear and compaction) can cause significant losses in shoot density and vigor, and in turn can promote weed encroachment.

#### **Plant wear and compaction tolerant grasses to alleviate losses in function and quality.**

- Wear and compaction are distinctly different stresses. Thus, selecting wear tolerant grasses does not necessarily equate to superior compaction tolerance.
- Selecting wear tolerant grasses can help to reduce compaction tendency, however, as superior wear tolerance provides greater shoot density and cushioning to help protect the soil.
- Selecting wear tolerant species such as perennial ryegrass does not insure wear tolerance because of the tremendous variation that typically exists among cultivars. Selecting the proper cultivar is equally important to selecting the proper species.
- Selecting wear tolerant turfgrass is just one of several management practices important in maintaining adequate grass cover under traffic, as cultural practices such as N fertilization and irrigation can influence morphological and anatomical characteristics associated with wear tolerance.

#### **Relative wear tolerance of cool-season turfgrasses.**

perennial ryegrass = tall fescue > Kentucky bluegrass > bentgrass = fine fescue > annual and rough bluegrass

**Redirect traffic patterns regularly whenever possible to reduce wear and compaction injury.**

- Even the most wear tolerant grasses need rest to promote recovery from wear injury.
- Grasses growing under low light caused by shading from tree canopies or buildings are especially intolerant of wear. Traffic should be redirected away from such areas.
- In extreme cases where traffic cannot be regularly and effectively re-routed it may be necessary to consider alternative surfaces other than natural turf.



*Re-route traffic or consider alternative surfaces in areas subject to heavy wear.*

**Follow a balanced fertility program to enhance wear and compaction resistance.**

- High shoot density provides cushioning and energy absorbing qualities, thereby protecting the turfgrass growing points from wear injury and reducing compaction tendency.
- Balanced nitrogen (N) input is necessary for optimum wear tolerance. Inadequately fertilized turf may not provide adequate vigor and density to maintain maximum wear tolerance.
- Over-application of N promotes excessive shoot growth and succulent tissues that can lead to greater wear injury.
- Optimum levels of potassium (K) are needed that are in balance with N to maintain good plant vigor.
- Adequate K is needed for cell wall thickening important in wear tolerance.

- For most fine textured soils K can be applied at levels that are approximately 50 to 75% of the total annual N. Higher levels for a N:K ratio closer to 1:1 are recommended for sandy soils.

### **Irrigate judiciously to promote the best traffic tolerance.**

- Irrigate to fully recharge the root zone and allow for mild soil drying to occur between irrigation events. Soil drying increases compaction resistance.
- Maintaining moist root zones at field capacity promotes succulent tissues and greater wear injury as well as promoting compaction tendency. Irrigation that provides moderate growth is preferred.

### **Mow intelligently to keep up energy reserves and maintain shoot density.**

- Moderately close mowing is preferred for maximum wear tolerance.
- Excessively close mowing depletes energy reserves important for wear recovery.
- Excessively close mowing can decrease shoot density and cushioning that can accelerate compaction tendency and increase injuries to turfgrass plants and end-users of the turf.

 <b>OBJECTIVE</b>	<b>Include turfgrass cultivation in the management plan to promote the overall health of the turf system.</b>
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### **Understand turfgrass cultivation.**

- Cultivation in the turfgrass arena is somewhat different than cultivation employed in cropping systems.
- In turf management, cultivation refers to any cultural practice that disrupts the soil surface.
- Cultivation practices include but may not be limited to aeration, dethatching, hard raking, or any other practice that opens the soil.

### **Manage soil compaction to reduce problems caused by alterations in the physical properties of the soil.**

- The decrease in total soil pore space associated with compaction can reduce drainage, reduce channels available for root growth and inhibit air exchange.
- Compaction can decrease soil oxygen and negatively impact plant respiration and growth.
- Compaction can alter infiltration and percolation rates, which alters irrigation practices and scheduling.
- Thatch is often found in association with soil compaction because of the unfavorable soil conditions for microbial activity and decomposition.

### Core aerate regularly for several management benefits.

- Core aeration releases built-up toxic gases, such as CO<sub>2</sub>, and allows the influx of O<sub>2</sub> into the root zone.
- Core aeration increases soil infiltration rates as a result of increased surface area, thereby reducing water runoff and puddling, and allowing wet soils to dry faster.

**Example:** 1,000 square feet of turf after a single aeration event using a  $\frac{3}{4}$  inch diameter tine, spaced two inches on center, with a tine penetration depth of 2 inches, would be equivalent to 2180 square feet of surface area.

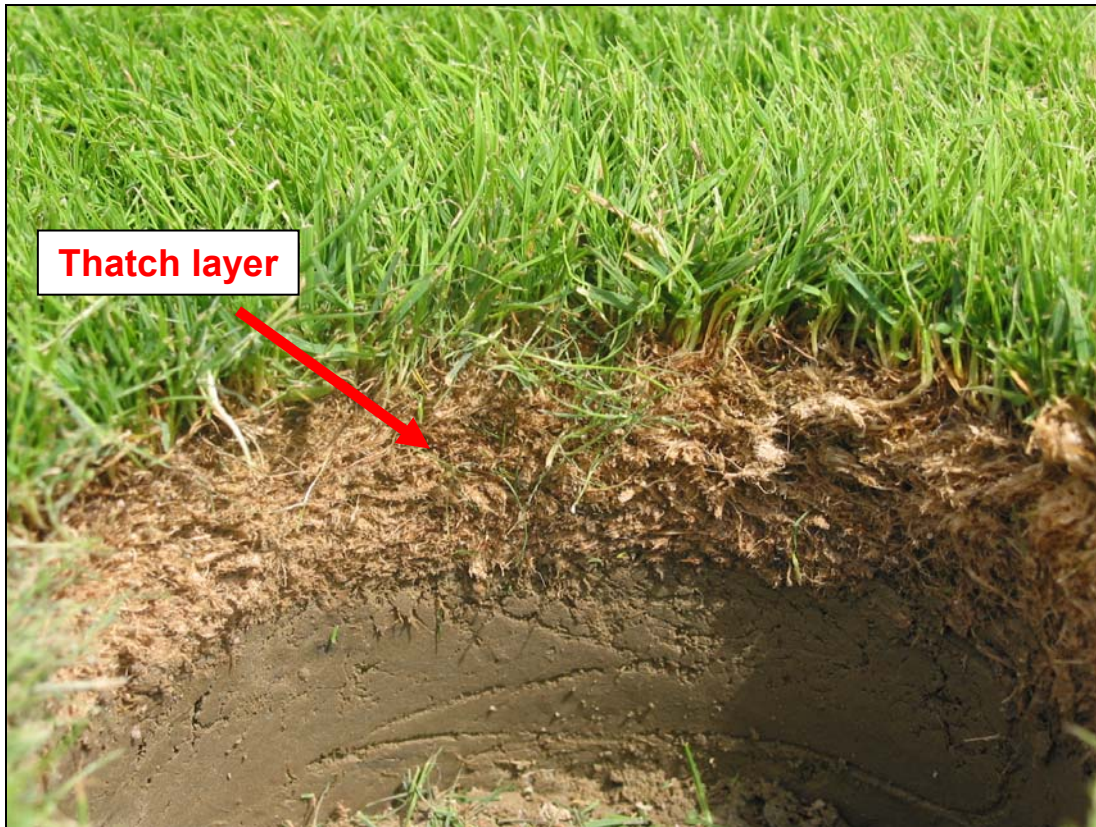
- Enhanced rooting occurs within core aeration holes.
- Core aeration increases plant uptake of nutrients, and promotes incorporation of immobile materials such as lime and phosphorus into the root zone.

### Monitor for thatch problems.

- The overall effect of a thick thatch layer is an unthrifty lawn which does not respond well to management practices and is easily injured by adverse weather conditions and pests.
- To examine the thatch layer, cut out a small, triangular-shaped plug of turf several inches deep.
- If the spongy layer of material above the mineral soil is more than  $\frac{1}{2}$  inch thick when compressed, consider implementing cultural practices to encourage decomposition of the thatch layer.
- Practices which discourage thatch build-up include frequent mowing, retention of clippings, reducing fertilization, and maintain pH at approximately 6.5.
- Mechanical methods to reduce and remove thatch include core aeration, verticutting, dethatching and power raking.

### Utilize core aeration to manage thatch.

- Favorable conditions for air exchange and microbial activity following core aeration lead to accelerated decomposition and subsequent thatch reduction.
- Heavy thatch ( $\frac{1}{2}$  inch to greater than 1 inch or more) should be removed by verticutting or power raking prior to core aeration.
- Substantial amounts of thatch can be physically removed by core aeration when thatch-containing plugs are collected and removed. The extent of thatch removal will vary with tine diameter, tine spacing, and number of passes but can be as much as 10% or more.
- Moderate levels of thatch ( $\frac{1}{3}$  to  $\frac{1}{2}$  inch or less) can be maintained by regular aeration and dragging and returning broken plugs.



*Thatch accumulates faster under growing conditions that inhibit rapid decomposition of turfgrass stem tissue.*

**Table 17. Benefits of commonly used cultivation methods associated with thatch, compaction, and seedbed preparation.**

(KEY: ◆ = yes, without indicating any level; ■ = to some extent; ● = to a major extent).

	Loosens thatch	Reduction of soil compaction			Promotes seed/soil contact
		None	Some	Significant	
<b>Method</b>					
Power raking	◆	◆			■
Vertical cutting	◆	◆			■
Slicing					
Spiking					■
Hollow tine coring				◆	●
Grooving	◆			◆	●
Solid tine coring			◆		■

### **Give appropriate attention to core aeration timing and frequency for maximum benefit.**

- Aeration should be timed to allow an adequate period for plant recovery. Whenever possible, cultivation operations should be performed during peak shoot and root growth periods of early spring and early fall.
- Spring and early summer cultivation is preferred to fall when annual bluegrass infestation is a problem. Fall cultivation is preferred when crabgrass is a problem.
- Fall core aeration is preferred when combined with fall overseeding, fertilization, and liming programs.
- Mid-summer aeration should be avoided because of the potential for excessive soil drying and the spread of diseases.
- Heavily trafficked sites (paths, areas that receive vehicle traffic, etc.) may be aerated 4 to 6 times per year depending on the soil type and the extent of traffic.
- Most lawn areas which receive little traffic will generally benefit from at least one or more core cultivations every year or two, depending upon site conditions and specific objectives.

### **Topdressing following cultivation practices can promote a more uniform surface.**

- Lawns can be topdressed with approximately  $\frac{1}{8}$  inch of topsoil similar to that found in the existing root zone, or with an appropriate compost or similar material to even out bumpiness and fill in core aeration holes or slits from dethatching operations.
- Effective topdressing requires detailed knowledge of physical and chemical properties of both topdressing material and existing soil.
- Using an inappropriate topdressing material often results in negative benefit, as dissimilar topdressing materials will not interact well with the existing soil.
- Addition of peat and other organic materials also must be done with care, as some materials can simulate thatch and incite similar turf problems.
- Topdressing materials should be tested for physical and chemical properties, and results should be kept on file.

### **Consider additional factors for effective core aeration.**

- Consider aerator tine length, diameter and spacing. The more core aerifier holes per square foot of compacted soil and the greater the penetration depth, the greater the benefit in alleviating compaction and promoting rooting and gas exchange.
- Avoid core aeration when compacted soils are dry which can increase machine stress and severely limit aeration effectiveness.
- Consider irrigating the soil before aeration to the desired depth of penetration to ease soil strength and tine resistance, but avoid core aeration when the soil is “too wet” which can be counter productive and increase soil compaction.
- Take care not to damage any parts of the irrigation system during the aeration process.

## SECTION 10

### WEED MANAGEMENT

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 <b>OBJECTIVE</b>	<b>Determine pest management action levels for weed infestations.</b>
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#### Develop site-specific action level guidelines for controlling weeds.

- No general action level guidelines for management of weed species in lawns are presently available.
- Pest management action levels for weed populations are very subjective and vary greatly based on the management program, desired quality and function for a lawn.

**Example:** a moderate infestation of broadleaf weeds may be allowable on a seldom used residential lawn area but unacceptable on a high-profile commercial lawn.

- Weed species action levels can be established even for a specific use area on a specific property based on careful monitoring and the history of the site.
- Action levels may vary according to weed species present.
- In most cases control measures will be curative. Preventive control may be used based on scouting information and on potential for future infestation.

 <b>OBJECTIVE</b>	<b>Establish and conduct a scouting program for weeds.</b>
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#### Scout regularly for weeds to inform management decisions.

- Scouting for weed species normally consists of visual observation and counting of the number of undesirable plants per unit area.
- Scouting should be done every time a turf manager is on a particular site, in addition to an all-inclusive, in-depth scouting event during late summer or early fall.
- The turf manager should use a back and forth or zig-zag pattern when scouting for weeds, with special attention to known problem areas.
- Observations can be recorded on a site map or added to a list with the location identified.



- In addition to recording weed species present, special attention should be given to areas of thin turf and possible causes, newly introduced weeds and historically problematic weeds that are not controlled with the current management program.
- Since many weed problems arise as a result of specific cultural problems, corrective action may be critical to minimizing future weed encroachment.



## OBJECTIVE

### Discourage weed infestations with non-chemical means.

#### Limit potential entry of weed seed into the system.

- Remove weeds, especially newly introduced weeds, by hand when appropriate.
- Prevent weeds from going to seed in lawns, adjacent gardens and border areas.
- Consider weed seed levels in selection of materials such as soil, amendments, compost, topdressing material, sod and other plant material.
- Use certified seed for establishment, making repairs, reseeding and overseeding.
- Use high quality, low weed level sod during renovation and establishment.
- Collect and remove clippings which contain weed seeds when appropriate.
- Set height of cut at maximum acceptable height.
- Reduce compaction and wear areas by re-routing traffic.

#### Create a growing environment that makes weed species less competitive.

- Maintain a dense and deeply rooted turf as the primary means of integrated weed management.
- Water judiciously; timing irrigation events to prevent moisture stress and avoid over-watering.
- Aerate to relieve compaction.
- Avoid turf cultivation during periods conducive for crabgrass germination (spring) if it is considered a weed at the particular site.
- Avoid turf cultivation during periods conducive for *Poa annua* germination (fall, peak *Poa annua* germination), if species is considered a weed.
- Overseed with desired turfgrasses in late summer-early fall if turf has thinned due to drought dormancy.

#### Supply adequate and balanced nutrition to yield a dense and well-rooted turf.

- Avoid high levels of fertility during the summer months when cool-season turfgrasses are stressed and easily out-competed by many weed species.
- If turf has thinned due to drought dormancy, provide adequate fertility once dormancy breaks to encourage recovery.
- Do not fertilize dormant or brown turf.



## OBJECTIVE

**Use herbicides intelligently when other means fail to acceptably control weed species present.**

### **Discourage herbicide resistance.**

- Select from different herbicide groups whenever possible, not relying on a single “group” (class) or mode-of-action.

### **Apply postemergence materials responsibly.**

- Be familiar with weed life cycles to apply herbicides at most vulnerable growth stages of weeds.
- Limit blanket applications to avoid unnecessary pesticide use and undue turf stress. Spot treat weeds when appropriate.
- Do not apply herbicides if temperatures are above or forecast to exceed 85 °F.

### **Apply preemergence materials responsibly.**

- Use preemergence or preventive herbicides only in areas where weeds occurred and were documented the previous season and can be expected to occur in current season.
- Select and use preemergence herbicides so as not to interfere with overseeding opportunities. Follow label recommendations.
- If there is annual weed pressure and turf dormancy is going to be allowed to progress at a site during the summer months, consider applying a preemergence material in the spring.
- Water-in preemergence herbicides as appropriate and according to label directions.
- Avoid cultivation following preemergence applications to maintain the protective barrier.

### **Consider fertility.**

- When using herbicides containing nitrogen, factor the amount of N applied into the fertility program for the particular lawn.
- Fertilize lightly after postemergence herbicide application when appropriate to aid the turfgrass in the filling of canopy voids left by dying and dead weeds.

## SECTION 11

### INSECT MANAGEMENT

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#### OBJECTIVE

**Determine pest management action levels for insect populations.**

**Use existing insect action level guidelines as a starting point for a specific site.**

- Site-specific action levels vary based on desired quality and use of the turf, pest potential, quality of monitoring, and history of the site.

**Table 18. Approximate threshold guidelines for turfgrass insect pests.**

INSECT	Approximate threshold per sq. ft.
Japanese beetle	8 to 15 larvae
Oriental beetle	8 to 15 larvae
Masked chafer	6 to 15 larvae
European chafer	3 to 8 larvae
Asiatic garden beetle	12 to 20 larvae
May beetle ( <i>Phyllophaga</i> )	2 to 4 larvae
Black turfgrass atenius	15 to 80 larvae
Annual bluegrass weevil	10 to 80 larvae
Bluegrass billbug	No good estimate available
Chinch bug	30 to 50 nymphs
Sod webworm, cutworm	No good estimate available

- Use guidelines for action levels for insects as general starting points only.

**Example:** some turf areas may lose turf cover or be subject to damage from grub-foraging animals such as skunks with 4 or 5 grubs per square foot, while others (with available irrigation, higher mowing heights, low traffic) may sustain populations of 25 to 30 grubs per square foot with no apparent damage.

- Keep records diligently to keep track of 'hot spots' and also for predicting future activity.

**Example:** a record beetle flight in early summer may be an indicator of the potential for damaging populations of grubs later in the summer and into the fall and the following spring.

 <b>OBJECTIVE</b>	<b>Establish and conduct a scouting program for insects.</b>
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**Monitor regularly for insects to inform management decisions.**

- Management decisions are often aided by visual scouting.
- Appropriate scouting techniques should be used for particular insect(s). Counts of insects per unit area are helpful in estimating overall populations.
- Record observations on a site map or to a list with the location identified.
- Note particular ‘hot spots’ or areas of early insect activity that might act as indicator points for future seasons.

**Table 19. Monitoring & sampling for turf damaging insects.**

<b>INSECT</b>	<b>TURF AREAS TO MONITOR</b>	<b>WHEN TO MONITOR</b>	<b>SAMPLING TECHNIQUES*</b>
<b>White grubs</b>	All turf	<i>Adults</i> - mid-June to September  <i>Larvae</i> - March to May, July to December	<i>Adults</i> - pheromone traps (oriental beetle, Japanese beetle) **  <i>Larvae</i> - soil sample
<b>Ants</b>	All turf	<i>Adults</i> - late April to late September	<i>Adults</i> - count active mounds per unit area
<b>Billbugs</b>	All turf, especially Kentucky bluegrass	<i>Adults</i> - May to early June  <i>Larvae</i> - June to August	<i>Adults</i> - soapy flush  <i>Larvae</i> - core float
<b>Chinch Bugs</b>	All turf; especially sunny, drought stressed areas and areas with thick thatch and sandy root zones.	<i>Adults</i> - June to late July	<i>Adults</i> - can float, visual inspection of soil/thatch interface

**Table 19. Monitoring & sampling for turf damaging insects (cont'd).**

<b>INSECT</b>	<b>TURF AREAS TO MONITOR</b>	<b>WHEN TO MONITOR</b>	<b>SAMPLING TECHNIQUES*</b>
<b>Cutworms</b>	All turf, especially closely mown areas	<i>Adults</i> - May to September  <i>Larvae</i> - late May to September	<i>Adults</i> - blacklight trap  <i>Larvae</i> - soapy flush
<b>Sod Webworms</b>	All turf, especially sunny areas, steep slopes & dry banks	<i>Adults</i> - late June - late August  <i>Larvae</i> - Late April - early June	<i>Adults</i> - visual observation at twilight, blacklight trap  <i>Larvae</i> – soapy flush
<p>* Refer to the table, 'Insect sampling techniques' below.</p> <p>** Use pheromone traps with care. They are useful for determining when beetle adults begin to fly, but can also potentially attract more damaging insects into an area.</p>			

**Use appropriate techniques for effective insect scouting.**

- Proper scouting techniques vary depending upon the target insect species.
- Correct scouting techniques are designed to effectively gauge the level of insect populations while minimizing turf disturbance.

**Table 20. Insect sampling techniques for scouting**

<b>Technique</b>	<b>Description</b>
<b>Soil sample</b>	Dig three sides of a square, 6 inches on a side (=0.25 sq. ft.) and 4-6 inches deep. Flip upside down on flat surface, e.g., a plywood board. Use a trowel to beat soil and roots on bottom of sod in order to dislodge larvae. Remove larvae and put in a container to count totals. Replace sod, water well, and sod should re-root. Alternatively, use a cup cutter to pull samples (=0.1 sq. ft.).
<b>Soapy flush</b>	Add 1 to 2 tablespoons of lemon scented liquid dish detergent to 1 gallon of water; pour over area 2 ft. by 2 ft. Caterpillars, earthworms and adults of some species will be irritated and crawl to the surface within 5 minutes (usually more quickly). Collect caterpillars and/or insect adults and put in a container to count totals. If sampling in mid-summer, rinse the area after counting insects to avoid scalding turf.
<b>Core float method</b>	Take a sample with a cup cutter, gently break apart turf and thatch, and look for insects. Place all material in dishpan with lukewarm water. Insects will float to surface.

<b>Can float method</b>	Remove the ends from 3 or 4 coffee cans. Pound empty cylinders (wet soil to soften) 2 to 3 inches into ground, fill with water, and wait 5 minutes to count insects floating to the surface.
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*Use a small board when breaking up soil samples for insect monitoring to minimize turf disruption and mess.*

 <b>OBJECTIVE</b>	<b>Use proper cultural practices designed to prevent insect populations from reaching damaging levels.</b>
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**Reduce environmental stress and maintain plant vigor.**

- Supply adequate and balanced nutrition through the fertility program to yield a dense and well-rooted turf.
- Time and deliver irrigation so as to prevent moisture stress.
- Manage excessive thatch by adjusting fertility levels, mechanical removal or other means.
- Set height of cut at maximum acceptable height.

### Keep up with needed repairs.

- Overseed with desired turfgrasses in late summer-early fall if turf has thinned due to drought dormancy or insect infestation.
- When turf has been dislodged by animals and birds seeking grubs, replace and roll to bring roots back into contact with soil.
- Use high quality sod free of turf damaging insects during renovation and establishment.

### Plant endophytic cultivars whenever possible.

- At present there are some endophytic cultivars of perennial ryegrass, tall fescue, hard fescue and Chewings fescue available.
- Endophytic cultivars have a beneficial fungus called an endophyte within the seed and above-ground portions of the plant itself.
- Endophyte-enhanced cultivars tend to be vigorous even under conditions of stress, and exhibit a level of resistance to foliar feeding insects such as sod webworms, and in particular chinchbugs and billbugs.
- Endophytes impart no tolerance or resistance to root feeding insects such as white grubs.
- Endophytic turfgrass cultivars should not be used where animals may graze.

### Encourage beneficial insects.

- The role of beneficial insects is crucial to thatch management, and to the overall health of the turf.
- Some beneficial insects, such as big-eyed bugs, are predators that may feed on eggs and larvae of turf-damaging insects.
- Unfortunately, some of the insecticides that are currently used in turf settings are 'broad spectrum' materials; this means they kill a wide range of insects, including many beneficial insects.
- Insecticide applications should be made only when sampling has demonstrated that a pest population has reached the threshold level, and only to areas for which infestation has been confirmed through careful monitoring.



#### OBJECTIVE

**Use insecticides intelligently when other means fail to acceptably control insect pest(s) present.**

### Discourage insecticide resistance.

- Rotate insecticide chemical classes as appropriate.
- For ease of reference, Insecticide Resistance Action Committee (IRAC) codes are available to aid in insecticide resistance management. Refer to UMass Extension's *2010-2011 Professional Guide for IPM in Turf for Massachusetts* or <http://www.irac-online.org>.

### **Consider pesticide characteristics when selecting an insecticide.**

- Some insecticides have curative effect, while others are designed to be preventive materials.
- Some turf insecticides act very quickly while others take much longer to kill the target insect.
- In addition, some materials persist for several weeks and remain active, while others break down in a matter of a few days.

### **Give particular consideration to potential human and environmental impacts when applying insecticides.**

- Understand the mobility and persistence of the material intended for use.
- Many materials are toxic to fish, aquatic invertebrates, and/or foraging bees. This information can be found under 'Environmental Considerations' on the pesticide label.
- Do not apply insecticides harmful to foraging bees to lawns in which white clover is in bloom.
- Use proper personal protective equipment (PPE) for mixing and application activities.
- Observe specified re-entry intervals.

### **Take steps to insure insecticide efficacy.**

- Use insecticides only when insect presence has been documented and those insects are in a susceptible stage.
- Many pesticide materials need to be 'watered-in'. Irrigate according to label directions before and/or after insecticide applications. This is especially important for soil dwelling insects.
- Test spray water source(s) regularly for pH.
- Consult the label for the appropriate temperature range for application. Some insecticides are less effective at lower temperatures, while others can damage turf when applied in hot weather.

### **Apply preventive insecticides responsibly.**

- Preventive materials are applied before a noticeable pest population develops, and are therefore not based on a current population exceeding a set action threshold.
- If scouting the previous year confirmed the presence of damaging populations, a preventive insecticide may be justified.
- Preventive insecticide should be used in conjunction with proper cultural practices that provide the best agronomic conditions for turf health.



## SECTION 12

### DISEASE MANAGEMENT

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#### OBJECTIVE

**Monitor and manage pressure and infection from turfgrass damaging diseases.**

#### **Set action thresholds for disease occurrence on a particular site.**

- Disease pressure and incidence are often significantly lower on lawn turf than on other more closely cut and more intensively managed areas, such as golf courses.
- Common lawn diseases are most often temporary and do not cause permanent turf damage, or damage that cannot be remedied with minor repairs.
- When severe disease outbreaks occur on lawns, it may often be a result of unusual weather conditions or an underlying agronomic problem.
- Thus, fungicide application is seldom warranted or recommended for most lawn areas.

#### **Scout regularly for diseases to inform management decisions.**

- Although disease outbreaks are less of a concern on lawns than weeds or insects, watching for disease is an important component of a complete monitoring program.
- The appearance of disease on a stand of turf is fundamentally dictated by interactions between three factors: temperature, amount and duration of moisture present, and the presence of an organism capable of causing disease.
- Careful attention to these three factors, along with a working knowledge of the preferred conditions of various diseases, can be critical for avoiding significant problems.

**Table 21. Monitoring for turf damaging diseases.**

<b>DISEASE</b>	<b>TURF AREAS TO MONITOR</b>	<b>WHEN TO MONITOR</b>
<b>Gray Snow Mold</b>	All turf.	Jan-Apr, 32-45°F. Prevalent after prolonged snow cover.
<b>Pink Snow Mold</b>	All turf.	Jan-May & Oct-Nov, 32-45°F. Active anytime during prolonged, cool weather. Requires no snow or other cover for disease.
<b>Leaf Spots/Blights/ Melting Out</b>	All turf, especially Kentucky bluegrass and fine fescues. More common in areas with high nitrogen fertility.	Apr-Oct, 45-75°F, especially April-Oct whenever prolonged leaf wetness results from rain, dew or irrigation.
<b>Rusts</b>	All turf, especially Kentucky bluegrass. More common in low mown areas and areas with compacted soil.	Jul-Oct, 45-75°F. Most common when turf is slow growing and/or droughty.
<b>Red Thread/Pink Patch</b>	All turf, especially perennial ryegrasses and fine fescues. More common on nutrient deficient turf.	Apr-Oct, 45-75°F, especially during prolonged periods of cool, wet weather with heavy dew and light rain and fog.
<b>Dollar Spot</b>	All turf. More common on dry, nutrient-deficient soils.	Jun-Sept, 45-80°F, especially during warm, humid weather with cool nights and heavy dews.
<b>Summer Patch</b>	All turf, especially annual bluegrass, Kentucky bluegrass, and creeping red fescue, and/or with excess thatch.	Jul-Sept, over 75°F, especially when soil temperatures are high. Symptoms often appear after a heavy rain.
<b>Brown Patch</b>	All turf, especially perennial ryegrass and tall fescue.	July-Sept, over 75°F, when days are hot, humid with warm nights, especially following rain.
<b>Fairy Ring</b>	All turf	April-Oct, 45-75°F. Puffballs and mushrooms occur most often after rain.



## OBJECTIVE

**Implement focused cultural practices as the primary defense against disease outbreaks on lawn turf areas.**

### **Fertilize judiciously and lime appropriately.**

- Apply fertilizer according to current recommendations and based on a soil test.
- Excess nitrogen will cause succulent growth that is more susceptible to disease, and some diseases are encouraged when nitrogen is deficient.
- Adjust pH according to soil test recommendations. Disease occurrence may increase at pH extremes (too high or too low).
- Time fertilization and liming to avoid disease critical periods (e.g. avoid fertilization in early spring and just before hot, humid weather).

### **Take herbicide applications into account.**

- Herbicides can stress turfgrasses and make them more susceptible to diseases. Apply carefully according to label directions and with attention to environmental conditions.
- Some herbicides may have fungistatic effect and provide some degree of disease control.
- Noting fungistatic occurrences may be useful for reducing or eliminating fungicide applications.

### **Irrigate with disease reduction in mind.**

- Disease-causing fungi reproduce by spores that, like seeds, need water to germinate and infect turf. Make every effort to reduce the duration of time that grass is wet from irrigation or dew.
- Time irrigation in order to minimize duration of leaf wetness. Dry turfgrass blades reduce disease by reducing infection.
- Water deeply and infrequently, and prevent significant moisture stress.
- Avoid light, frequent sprinklings (syrringing) except to prevent wilting in close-cut or shallow rooted turf or immediately following sod installation and during hot, dry weather.

### **When NOT to water turf.**



### Take proper mowing considerations.

- Mowing wounds turfgrasses and can spread pathogens (disease-causing organisms).
- Minimize wounding and shredding of grass blades by keeping blades sharp and adjusted properly.
- Mow when turf is dry whenever possible.
- Remove and properly dispose of clippings when diseases such as red thread and dollar spot are present at unacceptable levels.
- Mowers should be washed and mowing order of lawns should be modified when some lawns have active disease to avoid spreading pathogens. Alternatively, a dedicated mower can be used.
- Mowing in autumn until turf stops growing can help to reduce damage from snow molds.

### Reduce turfgrass stress.

- Modify the landscape where needed to improve air circulation and reduce shade.
- Reduce or eliminate traffic on areas with active disease infestation whenever possible.
- When compaction is contributing to plant stress, take appropriate measures to relieve compaction
- Manage excessive thatch by adjusting fertility levels or by mechanical removal.



#### OBJECTIVE

**Use fungicides only when sound cultural practices have not proven effective in acceptably managing a disease problem.**

### Apply fungicides responsibly.

- Obtain a laboratory confirmation of disease and a diagnostic report prior to any application, especially if you are unsure of the disease.
- Rotate fungicides based on chemical group to discourage resistance. For ease of reference, Fungicide Resistance Action Committee (FRAC) codes are available to aid in insecticide resistance management. Refer to UMass Extension's *2010-2011 Professional Guide for IPM in Turf for Massachusetts* or <http://www.frac.info>.
- Apply irrigation as necessary after fungicide applications.
- Use preventive fungicides only in areas where diseases occurred and were documented the previous season and/or can be expected to occur in the current season.

### Collect a turf sample for laboratory diagnosis.

- Obtain a laboratory confirmation of disease and a diagnostic report prior to any application, especially if you are unsure of the disease.
- Collect a 4-6 inch sample from the leading edge of a problem including roots and soil to a depth of at least 2 inches and foliage showing the symptoms.
- Keep the sample moist and cool, but do not water or seal tightly in plastic.

- Wrap the sample in several layers of newspaper and pack it snugly in a sturdy box.
  - Take the sample before spraying a fungicide.
  - Accurate disease diagnosis requires both a representative sample and sufficient information about the cultural practices and environmental conditions, therefore a turf disease case history should be submitted with the sample.
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## SECTION 13

### MANAGEMENT OF ABIOTIC PROBLEMS

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#### OBJECTIVE

**Monitor and manage abiotic stresses to reduce turfgrass damage and minimize environmental impact.**

#### **Determine action levels for abiotic problems at a particular site.**

- Abiotic problems are non-biological agents that have the potential to cause turf damage or impart stress.
- The turf manager should have a general knowledge of sound cultural practices as well as turf damaging abiotic factors and their management.
- Abiotic stresses and associated problems, including improper cultural management techniques, can influence turf function and quality as well as pest activity.
- Action levels should be based on knowledge of the desired quality and use of the turf, careful monitoring, and a history of the site.
- Action levels for abiotic problems may be very subjective and vary greatly based on the management program, desired quality and function for a lawn. For these reasons, no general action level guidelines for management of abiotic problems are presented.

#### **Establish and conduct a scouting program for abiotic factors that damage turf.**

- Visually scout turf areas at each site visit, noting conditions which may lead to turf damage or actual symptoms of abiotic problems.
- Conduct an inclusive, in-depth scouting event annually, during late summer or early fall.
- Regularly monitor weather conditions at a weather station representative of site conditions or through reputable online sources.
- Record observations on a site map or to a list with the location identified.
- Note and record particular 'hot spots' or symptomatic areas that might act as indicator spots in future seasons.
- Since many abiotic problems arise as a result of specific cultural problems, determining and using corrective action may be critical to minimizing future problems.

**Table 22. Recognition of abiotic problems.**

<b>PROBLEM</b>	<b>WHAT TO LOOK FOR</b>
<b>Winter desiccation</b>	Large areas of straw-colored grass especially where exposed to wind with little snow cover.
<b>Spring frost damage</b>	New growth killed back.
<b>Water and ice damage</b>	Straw-colored or rotted grass, especially where water collects on frozen soil.
<b>Salt damage</b>	Dead or yellowed grass along sidewalks, driveways, or roads where salt has been applied.
<b>Compaction</b>	Soil is hard. Turf is thin. Rooting is poor.
<b>Acid or alkaline soil</b>	Overall poor growth. Soil test indicates inappropriate pH for grass growth.
<b>Nutrient deficiency</b>	Yellowing or other discoloration; generally poor growth.
<b>Over-fertilization</b>	Exaggerated turf color, along with rapid growth rate; tissues succulent.
<b>Fertilizer misapplication</b>	Browned streaks lined with extra green growth can occur in areas of application overlap. Yellowed, nutrient deficient streaks may occur in missed areas.
<b>Wilt, drought or moisture stress</b>	Turf loses its luster, appears slightly off-color and 'foot printing' occurs.
<b>Overwatering</b>	Soil is saturated; grass is overly lush and may mat down easily.
<b>Poor drainage</b>	Waterlogged soil, puddling.
<b>Scalping</b>	Mowing height excessively low, especially on uneven terrain.
<b>Dull mower injury</b>	Turf develops grayish or brownish cast, close inspection reveals shredded leaf tips.
<b>Shade</b>	Turf is thin; leaves may appear elongated and succulent.
<b>Poor air circulation</b>	Increased leaf wetness duration, increased disease incidence.
<b>Excess thatch</b>	'Spongy' turf surface, water infiltration problems, thick layer of matter at soil interface.
<b>Excess traffic and wear</b>	Bruising and crushing injury to turf, compacted areas, loss of stand density.
<b>Animal urine damage</b>	Spots of browned or yellowed turf, perhaps with extra green growth around them.
<b>Foreign chemical (gas, oil, hydraulic fluid) damage</b>	Sudden scorched areas of turf.

**Use cultural practices that help to prevent or mitigate problems caused by abiotic factors.**

- Use proper species and cultivar selection, sound fertility, judicious irrigation, proper mowing and cultivation, integrated pest management strategies, and other appropriate cultural practices to avoid or mitigate abiotic problems.
- Take steps to remediate conditions conducive to damage from abiotic factors.
- Refer to other pertinent sections of this document regarding BMPs related to specific cultural practices.

**Refer to Appendix B, 'Calendar for Cultural Practices and Related Activities'.**

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## SECTION 14

### PESTICIDE CONSIDERATIONS

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#### OBJECTIVE

**Use pesticides to manage identified pests only when cultural practices do not provide adequate control.**

**Use sound cultural management as a first line of defense against pests.**

- When pest populations threaten to exceed or do exceed the action level at which unacceptable damage may occur, use of a pest management material may be warranted.
- Pesticides should be used only when other options and alternatives are not sufficient to manage the problem to the extent necessary.

**Consider biological control options.**

- Biological materials that have been proven to be effective should be considered first. Other pesticides should only be considered when alternative options will not adequately manage the target pest.
- When employing biological control options, the turf manager must know what to expect from these products and how to maximize their effectiveness.

**Plan ahead.**

- Diligent planning helps to ensure that an application adequately controls the target pest, is cost effective, has a minimal environmental impact, and ensures the safety of turf users.
- Plan the treatment location. Spot or target treat in place of making blanket applications whenever possible.



#### OBJECTIVE

**Select and use pest management materials based on quality expectations, pest action threshold, and characteristics of the material.**

**Consider pesticide characteristics and other information when selecting a pesticide.**

- Is there an identified justification for use?
- Will the material manage the target pest?

- Is a curative or preventive application necessary?
- What is the potential for exposure to applicators and others?
- What is the impact on non-target and beneficial organisms?
- What is the potential for environmental impact?
- What is the chemical class (mode of action)?
- What is the proper timing based on the stage of development of the pest?
- What is the cost?

**Carefully evaluate the characteristics of a pesticide material:**

- persistence
- solubility
- mobility
- risk of groundwater contamination
- mammalian toxicity
- effects on non-target organisms
- speed of action
- length of residual

**Note:** Information on characteristics of particular pesticides can be found on the pesticide label, the MSDS sheet, or in informational databases such as EXTOKNET (<http://extoxnet.orst.edu>).

**Take special considerations for use of preventive pesticides within an IPM program.**

- Pesticides may have either preventive or curative action against the pest for which they are used. Preventive materials are applied before a noticeable pest population develops. Curative materials are applied when it is apparent that a pest population may reach the action level.
- Pesticides should be used preventively in an IPM program only when damaging levels of a pest have been previously identified through monitoring, and reasonable evidence exists to suggest that the population will exceed the action level in the future.
- Preventive applications should not be made outside of an IPM plan. The decision to use a preventive pesticide application should always be based on determination of action levels in conjunction with scouting.
- There may be instances in which using a preventive material is the best option.

**Example:** A decision to make an application of a preemergence herbicide for the control of crabgrass and other annual grassy weeds should be based on scouting and records from the previous growing season. Though there may be no actual crabgrass plants present at the time of herbicide application, the documentation of the previous season's infestation and the knowledge of the life cycle of the plant would lead to a justifiable decision to use a preemergence herbicide.

**Example:** In the management of white grubs there are few cultural practices or effective biological materials available. In Massachusetts, the use of the most effective curative material, trichlorfon, is not allowed on school properties as specified in the Children and Families Protection Act. The only option for effective management of damaging levels of grubs in this circumstance is preventive application. Therefore, effective management of white grubs may require the use of a preventive pesticide application. It must, however, be based on scouting or determination and documentation of potential for damaging insect population levels from the previous season or seasons.

### **Evaluate unconventional and scientifically unproven pest management materials and methods.**

- If the efficacy of a management material or method has not been determined through unbiased research, then it is prudent for the turf manager to test and evaluate the material on a specific site.
- Unconventional and scientifically unproven pest management materials and techniques should be tested and compared directly to an untreated area to determine the response of the specific pest management agent.
- The use of an ineffective product should not be considered simply because the product is biological or organic.
- When using unconventional and scientifically unproven materials, it is critical to set realistic expectations with the customer or client regarding potential outcomes.

 <b>OBJECTIVE</b>	<b>Apply pesticides in a manner consistent with labeling and compliant with regulations, and with environmental and human safety as priorities.</b>
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### **Comply with laws and regulations regarding the use of pesticides.**

- Know and comply with all federal, state and local regulations (see Appendix F for New England and New York state pesticide regulatory agencies).
- Use only allowed materials. Determine the registration status of a pesticide prior to applying it.
- Pesticide applications should only be made by properly licensed and/or certified pesticide applicators.
- Follow appropriate posting and notification requirements in accordance with regulations.
- By law, thorough records of all pesticide applications must be kept.
- Make applications of pesticides according to label directions.
- Carry out pesticide applications in a manner designed to protect water and other natural resources.

### **Consider application conditions.**

- Consult the pesticide label for drift and volatility risks associated with the material.
- Avoid application of any pesticide immediately prior to or during windy conditions or heavy rainfall that could result in unintended drift or runoff.
- Consult the pesticide label for specified air and soil temperature ranges appropriate for application.

### **Plan ahead when preparing spray mixtures.**

- Mix only the amount of pesticide needed to do the job.
- Leftover spray mixture needs to be applied according to pesticide label instructions.

### **Record required and pertinent information when making a pesticide application.**

- Pesticide application records must be kept as required by law.
- Use records of applications provide valuable information when assessing and planning for pest management strategies.

#### **Suggested points for pesticide application records:**

- date and time of application
- product brand name
- active ingredient
- formulation
- amount used
- application equipment used
- application rate
- target pest
- growth stage of pest
- treatment location
- temperature at application
- wind speed at application
- rainfall before/after application
- pH of water used to apply materials
- efficacy of application



## OBJECTIVE

**Store, handle, transport and dispose of pesticides in a manner consistent with labeling, compliant with regulations, and with environmental and human safety as priorities.**

**Store, mix, load, handle and transport pesticides with the same level of care devoted to pesticide applications.**

- The quality of surface water, groundwater and soil can be degraded in areas where pesticides are stored under inappropriate conditions, improperly mixed and loaded into application tanks and where equipment is washed and rinsed after application.
- Accidents involving spills or leakages may have serious health and environmental consequences.

**Evaluate any pesticide storage location carefully to determine its suitability.**

- The potential harm to human health and the environment due to spills, contaminated runoff or fires should be assessed.
- Pesticide storage should be restricted to a first story room or cabinet which has direct access to the outside.
- Pesticides should not be stored in basements.
- Pesticides should not be stored outdoors in the open.
- The storage location should be accessible in the event of an emergency situation.
- The storage location should be located away from direct sunlight, freezing temperatures and extreme heat.
- Where practical, the storage location should be located close to the mixing or loading area to minimize the distance that chemicals are carried.
- Pesticides should be stored away from fertilizer, food, feed, potable water supplies, veterinary supplies, seeds and personal protective equipment to avoid contamination.



*Store pesticide materials in a dedicated location whenever possible.*

**Know that safety is the key element in pesticide storage.**

- The storage area should be properly identified with signs such as, “Pesticide Storage Area.”
- The storage location should be securely locked at all times and access should be limited to only individuals trained in pesticide use.
- The storage location should be adequately ventilated.
- Minimal quantities of pesticide materials should be stored whenever possible.
- A list (inventory) of the products being stored should be posted on the outside of the storage location. A duplicate list should be retained off-site in case of emergency.
- Material Safety Data Sheets (MSDS) for stored pesticides should be available in a location adjacent and/or outside of the storage location.
- Pesticides should be stored in accordance with their label requirements in their original container with the label clearly visible.
- Pesticides should always be kept off the ground to prevent the accumulation of water in or under the containers.
- Separation of pesticides by hazard and function is essential. Flammable pesticides should be stored separately from non-flammable pesticides, in a fire proof cabinet for example. Fungicides, herbicides and insecticides should be stored in separate locations of the storage area to prevent cross contamination and accidental misuse.

- Dry pesticides should be stored separately from and above the level of liquid pesticides to avoid wetting from spills.
- Secondary containment vessels (such as plastic containers) should be used for liquid pesticides, whether they are at risk of leaking or not.
- If containers are in danger of leaking, they should be placed in an oversized plastic container or plastic lined (leak proof) cardboard box with vermiculite or other non flammable absorbent material for spill protection.
- Clean up supplies for spills (kitty litter, shovel, plastic bags, etc) should be kept in the pesticide storage area.
- Pesticides shall not be stored in the same place as ammonium nitrate fertilizer.
- Particular care should be taken if storing phenoxy herbicides (such as 2,4-D and MCPA) due to their volatility.
- Exposure to sunlight and extreme temperatures can lead to chemical breakdown of pesticides; therefore pesticides should not be stored in proximity to windows unless windows are covered.
- Because shelf life is difficult to predict, pesticides should not be stored longer than two years. The purchase date and the date that the container was opened should be written on the pesticide container.
- All applicators and staff should be trained in the particulars of pesticide handling and the safety/storage/handling procedures in place at the business or facility.

**Avoid mixing pesticides in areas where a spill, a leak or overflow could allow pesticides to get into water systems.**

- The mixing and/or loading of pesticides should not occur within four hundred feet of any private or public drinking water supply or two hundred feet of surface water.
- Pesticide application equipment or mix tanks should not be filled directly from any water source unless a back siphon prevention device is present.
- Mixing should not occur on gravel or other surfaces that allow spills to move quickly through the soil.
- A tank should never be left unattended while it is being filled.

**Wear personal protective equipment (PPE) appropriate for the material(s) being handled when mixing and loading pesticides.**

- A description of appropriate PPE can be found on the pesticide label.
- PPE should be in place before opening the pesticide container.
- A respirator should be worn when the potential exists for exposure to dusts or vapors.

**Take appropriate care to account for potential pesticide spills and fate of rinsing and wash water.**

- All transfers of pesticides between containers, including mixing, loading and equipment cleaning, should be conducted over a spill containment surface.

- Spill containment surfaces should be designed to intercept, retain and recover spillage, leakage and wash water.
- Containment needs depend on the quantities of pesticides that are being mixed and loaded. If mixing small quantities, a tarpaulin can be sufficient to contain any spills. If mixing large quantities regularly, the construction of a mixing/loading pad is an option to consider.
- Washing and rinsing of pesticide residues from application equipment, mixing equipment or other items used in storing, handling or transporting pesticides should occur on a containment pad.
- In order to reduce the need to frequently wash application equipment and to avoid cross contamination, application equipment can be dedicated for use with certain types of pesticides.

**Develop an emergency response plan and share it with all individuals responsible for the handling of pesticides.**

- An emergency response plan should list actions to take and personnel to contact in the event of a spill or accident.
- The plan should also include the names and quantities of pesticides present; the location of the property including a map with directions; the names, addresses and telephone numbers of the business owner and key employees; a plan of the facility; and the location of emergency equipment supplies including breathing equipment and protective equipment.
- A copy of the plan should be readily available at the pesticide storage location.
- Copies of the plan should be given to the local police department and fire department.
- Applicators and other staff should receive emergency response-related training.
- The plan should be available in English and any additional languages required for comprehension by all workers.

**Install effective fire prevention mechanisms and update them as necessary.**

- Appropriate fire prevention and emergency procedures for the pesticide storage location should be devised in consultation with the local fire department.
- An automatic smoke detection system or smoke and heat detection system should be installed.
- Suitable methods for extinguishing fires should be installed, such as the appropriate type and number of fire extinguishers.
- All electrical fixtures and appliances should be non-sparking units approved for use in facilities storing flammable and combustible liquids.



### **Take appropriate personal safety considerations at the pesticide storage location.**

- The phone number for a Poison Control Center should be posted in a prominent location.
- A first-aid kit should be readily available immediately outside of the storage area.
- Appropriate personal protection equipment such as respirators, chemical resistant (CR) gloves, CR footwear, coveralls with long sleeves, protective eyewear, CR headgear and CR aprons should be available as needed.
- Workers should be instructed in the correct procedure for the removal of contaminated clothing.
- Eye wash stations or portable eye wash bottles should be easily accessed by each person engaged in the operation and should be capable of flushing eyes for a minimum of fifteen minutes.
- Routine wash up facilities, equipped with soap, hand cleanser and single use paper towels should be available near the storage location.

### **Account for pesticides spills or accidents.**

- Contact information for emergency response providers should be readily available.
- Absorbent material such as re-usable gelling agents, vermiculite, clay, pet litter or activated charcoal should be on hand along with a garbage can and shovel to quickly contain and clean up any spills.
- All discharges to the environment or spills must be recorded. The records should include the date and time of the incident and the cleanup.

### **Take proper safety precautions in order to ensure safe transportation of pesticides.**

- The driver of the vehicle should be a licensed or certified pesticide applicator.
- Pesticide containers should be stored in a dry and lockable portion of the vehicle but not in the same compartment as the driver, and should be secured in place.
- A binder of appropriate pesticide labels and MSDS sheets should travel with the pesticide containers at all times.
- Emergency supplies should be kept on-board the vehicle including emergency phone numbers, a first aid kit, fire extinguisher(s), PPE (gloves, goggles, etc) and clean up supplies for spills (kitty litter, shovel, plastic bags, etc).
- At least 5 gallons of potable water should be carried for emergency eye or skin decontamination.
- All traffic laws should be obeyed at all times.
- A daily transportation/use log should be kept.

**The daily transportation/use log could include the following:**

- pesticide material on board
- driver's name and license number
- daily weather conditions (windy, rain, overcast, sunny etc.)
- if liquid, who filled the truck
- how many gallons of product in each tank
- what and how much of each granular product was loaded daily
- how much product was used for daily work

**Take proper safety precautions to ensure safe disposal of pesticides and containers.**

- An improperly disposed product can be hazardous to people and the environment.
  - Pesticide containers should be triple-rinsed when emptied.
  - Rinse water should be poured into a spray tank and applied to a registered site.
  - Triple-rinsed containers are considered non-hazardous and should be disposed of according to state recommendations.
  - Never reuse an empty pesticide container.
  - Applicators are advised to use pesticides in the same year of purchase whenever possible and to store pesticides properly in order to avoid the accumulation of unusable pesticide products.
  - Pesticide products that can no longer be used and need to be disposed of are considered hazardous waste.
  - Contact the Massachusetts Department of Agricultural Resources at 617-626-1781; <http://www.mass.gov/agr/pesticides> or the pesticide regulatory agency in your state for current regulations for pesticide disposal.
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## SECTION 15

### SELECTION & MANAGEMENT OF EQUIPMENT

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#### OBJECTIVE

**Select and manage equipment so as to minimize energy consumption, maximize function, and protect water and other natural resources.**

**Select and maintain machinery with functionality, energy efficiency and minimal environmental impact as priorities.**

- Consider optimum performance, cost, low energy use and reduced emissions when procuring equipment.
- Keep equipment in safe working order.
- Know and comply with equipment safety guidelines.
- Carry out all recommended preventative maintenance on machinery.
- Set mowing equipment at the correct height. Sharpen and balance blades as required for the machine.

**Maintain product reference files or owner's manuals or have access to such information.**

- Create and maintain a reference file with pertinent information on equipment.
- Maintain records of routine maintenance, service procedures, upgrades, and other related information.

**Regularly calibrate spreading and spraying equipment.**

- Calibration of application equipment ensures proper application rates and decreases the likelihood of poor efficacy or undesirable turf response.
- Calibrate application equipment monthly and perform a check daily (any day piece of equipment is used) including visual confirmation of nozzle and spreader delivery.
- Calibrate sprayers when new nozzles are installed or when other parts of the system (e.g. pump, meter) are repaired or replaced.

**Purchase locally or regionally produced materials and services whenever possible.**

- Use of local outlets decreases transportation emissions and costs.
- Make use of locally or regionally produced fertilizers (particularly those from composted plant or food wastes), composts, soil amendments and other materials as a means of increasing regional sustainability.

## APPENDIX A TURF PEST DAMAGE MONITORING CHART

This chart indicates when peak periods of damage are most likely to occur in the case of diseases and insects, and when seed will begin to germinate in the case of weeds. It is intended for use as a guide for monitoring pest activity and for pinpointing time periods when pest damage may occur. Please refer to the monitoring guides that follow for further information. This chart is NOT intended to indicate when applications of pesticides should be made, if at all.

<i>Weeds</i>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>Comments</i>
Weed Scouting Period				.....	.....	.....	.....	.....	.....	.....	.....	.....	Most weeds are large enough for easy identification.
Crabgrass and other Annual Grasses				.....	.....	.....	.....						Period of peak germination.
Annual Bluegrass								.....	.....	.....			Period of peak germination. May develop seed heads earlier in season if weather is favorable.
Yellow Nutsedge					.....	.....	.....						Sedges have triangular, solid stems, in contrast to the round, hollow ones of grasses.
Winter Annual Broadleaves								.....	.....	.....			Period of peak germination.

<b>Weeds</b>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<b>Comments</b>
Summer Annual Broadleaves				.....	.....				.....				Period of peak germination.
Perennial Broadleaves					.....			.....					Period of peak germination.

<b>Insects</b>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<b>Comments</b>
White Grubs			=====						=====				Turf appears to suffer drought stress. Skunks, raccoons, and crows may tear up the turf. Turf may pull up "carpet like."
Ants				=====									Mounds in turf. Mound activity begins in mid-April to mid-May.
Billbugs							=====						Areas wilt and do not respond to watering. Sawdust-like material in thatch. Turf is easily tugged loose. Adults active in late May – mid June.

<i>Insects</i>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>Comments</i>
Chinchbugs							—	—					Wilted or browned areas, most severe in sunny or sandy areas.
Cutworms						—	—						Burrows surrounded by brown patches, green frass may be present.
European Crane fly			—	—						—	—		Larvae normally feed in the top inch of the soil, and can be found even in the winter months. Pupae may be seen in late Aug.-Sept., and adults emerge in September.
Common (Marsh) Crane fly						—	—						Two generations each year, with new adults emerging in late April or early May. Second generation adults emerge in September.
Sod Webworm				—	—	—	—						Discrete browned areas which coalesce later. Most common in sunny areas. May cause damage in late spring.

<b>Diseases</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>	<b>Comments</b>
Gray Snow Mold	.....	.....	.....	.....									Matted grass covered with white-gray mycelium. Small reddish, brown, or yellow sclerotia present.
Pink Snow Mold	.....	.....	.....	.....	.....								Small orange brown to tan spots. Under humid conditions white to pink mycelium at margins.
Leaf Spots/Blights/Melting Out				.....	.....	.....	.....	.....	.....	.....			Oval or eye-shaped, dark bordered spots; dark specks (fruiting bodies) may be present in older diseased tissue.
Rusts							.....	.....	.....	.....			Irregular pattern of bright orange, yellow, reddish-brown pustules on the grass blades. Powdery orange spores.
Red Thread/Pink Patch				.....	.....	.....	.....	.....	.....	.....			Pink-red, often gelatinous mycelium on leaves when moist. Tiny pink cotton candy-like puffs of spores.

<i>Diseases</i>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>Comments</i>
Dollar Spot						.....	.....	.....	.....				Straw-colored silver dollar-sized spots. Leaf bands with brown or reddish-brown borders. White mycelium when wet.
Summer Patch							.....	.....	.....				Circular patches or rings of straw-colored grass 6-8 inches across. Center may be green. Common in annual bluegrass.
Brown Patch						.....	.....	.....	.....				1'-3' patches of light brown grass. Gray to white (smoke ring) mycelium at edge of patch may be present in moist conditions.
Fairy Ring				.....	.....	.....	.....	.....	.....	.....			Rings or arcs up to 15' across often with outer ring of dark green grass. Mushrooms may be present in ring.



## APPENDIX B CALENDAR FOR CULTURAL PRACTICES AND RELATED ACTIVITIES

This chart summarizes when turf management practices are most effective as to timing of fertilization, mowing, irrigation, liming, soil testing, cultivation, and planting activities. These dates are only guidelines and are **not** intended to indicate absolute start and end dates for all regions of Massachusetts. Consult the appropriate pest sections in this guide for cultural practices recommended for pest management.

<i>Cultural Practice</i>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>Comments</i>
Cultivation (aeration, dethatching)					-----	-----			-----	-----			Practice during peak shoot growth; terminate 2 weeks before low or high temperature stress. Fall cultivation is often preferable due to annual grass weed pressure in spring.
Fertilization					-----	-----		-----	-----		-----		If 1 time per year, apply in early fall. If 2 times per year, apply in spring and early fall, If 3 times per year, apply in spring followed by early fall and late fall.
Irrigation							-----	-----					Irrigate at leaf roll/fold (mild stress), avoid over-watering.
Liming			-----	-----	-----	-----	-----	-----	-----	-----	-----		Apply any time the ground is not frozen, more effective with aeration.

<b>Cultural Practice</b>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<b>Comments</b>
Mowing				.....									Continue to mow using the '1/3 Rule' until shoot growth ceases.
Planting (seeding, over-seeding)				.....					.....				Late summer - early fall plantings are preferred followed by spring. Avoid early summer and mid-summer plantings.
Soil testing			.....										Sample anytime the ground is not frozen; avoid recently fertilized and limed areas.

Development and implementation of a nutrient management plan (NMP) are critical to the proper management of the turf with environmental protection and enhancement as priorities. A nutrient management plan should address not only sound agronomic practices as they relate to the function of the turf, but also the protection of natural resources, particularly water. The following guidelines outline the components of a nutrient management plan. These components, appropriate for all types of turf, are covered in greater detail in Section 7: Soil and Nutrient Management.

**A complete NMP should include:**

- Site analysis and mapping.
  - Identification and mapping of environmentally sensitive areas as well as areas at high risk for off-site movement of nutrients.
  - Mapping of specific buffer zones delineated in environmentally regulated areas such as but not limited to Zone I wellheads, wetlands and certain coastal zones, and for protection of environmental resources.
  - Mapping, including measured square footage or acreage, of areas being fertilized or receiving nutrient containing materials.
  - Soil tests to determine chemical and physical condition of the soil and to ascertain recommendations for adjustments.
  
- Determination of:
  - need for nutrient inputs based on soil testing, turf function and quality desired, and proximity to environmentally sensitive sites.
  - lowest rate of input of nitrogen, phosphorus and other nutrients that will produce dense turf cover and promote deep rooting.
  - form (source) of nutrients appropriate for the management plan and the use of the turf on the site.
  - appropriate placement of fertilizer and nutrient containing materials.
  - frequency of fertilizer and nutrient containing material applications based on the nitrogen characteristics of each material.
  - timing of fertilizer applications so that maximum nutritional availability corresponds with periods of active turfgrass growth:
    - fertilizer and other nutrient containing materials should not be applied before spring green-up or when turf is dormant.
    - fertilizer and other nutrient containing materials should not be applied when the ground is frozen.
    - fertilizer and other nutrient containing materials should not be used as de-icers.

- Considerations for phosphorus (P):
  - determination of phosphorus (P) levels by soil test, and where and when application of phosphorus containing materials may and may not be allowed.
  - application of phosphorus containing fertilizers and other nutrient containing materials, regardless of the source of nutrients or the purpose of the application, should not exceed levels recommended by a soil test.
  - accounting of all phosphorus inputs into the management program and turf system. These may include, for example: fertilizers; turfgrass clippings retained in the system; composts, compost derivatives and other organic amendments; topdressings and other materials.
  - ample available P is critical to the success of turf establishment, renovations and major repairs. Levels of P applied in conjunction with such activities should be adequate for rapid turfgrass germination, growth and development.
  
- Considerations for nitrogen (N):
  - determination of nitrogen (N) fertilization need based on turfgrass species, time of year, turf vigor and plant response, and frequency of turf use.
  - determination of nitrogen rate based on turf needs as influenced by turf function and use as well as by presence of and proximity to environmentally sensitive areas, keeping N level to the lowest possible level required to realize management objectives while protecting the environment.
  - use of slow release sources of N as often as possible based on management objectives.
  - accounting of all N inputs into the management program and turf system. These may include, for example: fertilizers; retained turfgrass clippings; composts, compost derivatives and other organic amendments; topdressings; corn gluten used as an herbicide or fertilizer; and carryover N from prior seasons.
  
- Implementation of cultural practices that maximize nutrient uptake by plants, reduce nutrient waste and reduce off-site movement of nutrients.

These practices include:

- minimization of bare soil and maintenance of dense turf cover to reduce erosion, prevent runoff and increase nutrient retention within the turf/ soil system.
- implementation of practices that result in rapid establishment of turf following new planting or repairs.
- application of fertilizer and other nutrient containing materials only to turf, avoiding designated environmentally sensitive areas.
- application of fertilizer and other nutrient containing materials in a manner that prevents entry into surface waters or conduits such as catch basins that lead to surface waters or other environmentally sensitive areas.

- application of fertilizer and other nutrient containing materials so as not to fall on hardscapes such as driveways, sidewalks and roadways as well as non-vegetated surfaces. Should materials inadvertently land on such surfaces they should be removed promptly and handled properly.
  - handling of turfgrass clippings in an appropriate manner:
    - retention of clippings within the turf system whenever possible.
    - management of turfgrass clippings so that they are not allowed to enter surface waters or conduits such as catch basins that lead to surface waters.
    - clippings that are removed should be composted or handled in a manner that does not to pose a threat to the environment.
  - mowing at the highest end of the proper mowing height range for the grasses and cultivars present, and for the use of the turf, with the goal of maintaining turf density and maximizing rooting.
  - irrigation practices that promote infiltration and plant uptake, that do not lead to runoff and leaching, and that encourage deep and extensive turfgrass rooting.
  - relief of compaction through appropriate cultural practices such as core aeration.
- Implementation of proper storm water management techniques aimed at reducing off-site movement of soil and nutrients.
  - Detailed application records for inputs of fertilizer and nutrient-containing materials.

**Contact Information for Lawn and Landscape  
Turf Best Management Practices Project Partners****University of Massachusetts Extension Turf Program**

[www.umassturf.org](http://www.umassturf.org)

Mary Owen  
Extension Specialist and Team Leader, Turf  
800 Pleasant Street  
Rochdale, MA 01542  
tel 508-892-0382, fax 508-892-4218  
[mowen@umext.umass.edu](mailto:mowen@umext.umass.edu)

Jason Lanier  
Extension Educator  
308 French Hall  
University of Massachusetts  
Amherst, MA 01003-9316  
tel 413-545-2965, fax 413-545-3075  
[jdlanier@umext.umass.edu](mailto:jdlanier@umext.umass.edu)

**Massachusetts Department of Agricultural Resources**

[www.mass.gov/agr](http://www.mass.gov/agr)

251 Causeway Street  
Boston, MA 02114  
tel: 617- 626-1700, fax: 617-626-1850

**Massachusetts Farm Bureau Federation**

[www.mfbf.net](http://www.mfbf.net)

466 Chestnut Street  
Ashland, MA 01721-2205  
tel 508-881-4766

## APPENDIX E

# Lawn and Landscape Turf Best Management Practices Reference List

A reference library should have a selection of materials that cover the fundamentals of turf and pest management. Following are some suggested reference materials for use in developing and implementing IPM-based BMPs for lawn and landscape turf. For a more in-depth listing, visit the UMass Turf Program website, <http://www.umassturf.org>.

### Current Turf Management Recommendations:

Owen, M., and J. Lanier, eds., 2010. **Professional Guide for IPM in Turf for Massachusetts**, 2010-2011. University of Massachusetts Extension Turf Program, Amherst, MA. <http://www.umassturf.org>.

### General Turf References:

Christians, N., 2007. **Fundamentals of Turfgrass Management - Third Edition**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Fry, J. and B. Huang. 2004. **Applied Turfgrass Science and Physiology**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Sachs, P.D. 1996. **Handbook of Successful Ecological Lawn Care**. The Edaphic Press, P.O. Box 107, Newbury, Vermont 05051

Turgeon, A.J., 2007 **Turfgrass Management – Eighth Edition**. Prentice-Hall. (800) 282-0693. <http://www.prenhall.com>

### Specialized Turf References:

Abbey, T.M. **Turfgrass Nutrient and Integrated Pest Management Manual**. UConn IPM Program. <http://www.hort.uconn.edu/ipm/turf/htmls/turfman.htm>

Brede, D. 2000. **Turfgrass Maintenance Reduction Handbook: Sports, Lawns, and Golf**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Carrow, R.N., D.V. Waddington, and P.E. Rieke. 2002. **Turfgrass Soil Fertility and Chemical Problems: Assessment and Management**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Christians, N., and M.L. Agnew. 2008. **The Mathematics of Turfgrass Maintenance – Fourth Edition**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Gussack, E., and F.S. Rossi. 2001. **Turfgrass Problems: Picture Clues and Management Options**. (3.5" x 7" pocket book). Cornell University Natural Resource, Agriculture, and Engineering Service (NRAES). (607) 255-7654; <http://www.nraes.org>

### **Turf Disease References:**

Burpee, L.L. 1994. **A Guide to Integrated Control of Turfgrass Diseases: Vol. 1 - Cool Season Turfgrasses**. GCSAA Reference Material. 1421 Research Park Dr., P.O. Box 927, Lawrence, KS 66044-0927. (800) 472-7878; <http://www.gcsaa.org>

Couch, H. B. 2000. **The Turfgrass Disease Handbook**. Krieger Publishing Co., P.O. Box 9542, Melbourne, FL 32902-9542. (321) 724-9542; <http://www.krieger-publishing.com>

Schumann, G.L. and J.D. MacDonald. 1997. **Turfgrass Diseases: Diagnosis and Management CD-ROM**. APS Press, 3340 Pilot Knob Rd., St. Paul, MN 55121. (800) 328-7560; <http://www.apsnet.org>

Smiley, R.W., P.H. Dernoeden, and B.B. Clarke. 2005. **Compendium of Turfgrass Diseases – Third Edition**. APS Press, 3340 Pilot Knob Rd., St. Paul, MN 55121. (800) 328-7560; <http://www.apsnet.org>

Vargas, J. 2004. **Management of Turfgrass Diseases – Third Edition**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

### **Turf Insect References:**

Brandenburg, R.L. and M.G. Villani. 1995. **Handbook of Turfgrass Insect Pests**. The Entomological Society of America. ESA Sales, P.O. Box 177, Hyattsville, MD 20781-0177. (301) 731-4535; <http://www.entsoc.org>

Potter, D. A. 1998. **Destructive Turfgrass Insects: Biology, Diagnosis, and Control**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Vittum, P., M. G. Villani, and H. Tashiro. 1999. **Turfgrass Insects of the United States and Canada**. Cornell University Press, (607) 277-2338 x 251; <http://www.cornellpress.cornell.edu>

### **Turf Weed References:**

McCarty, L.B., J.W. Everest, D.W. Hall, T.R. Murphy, and F. Yelverton. 2008. **Color Atlas of Turfgrass Weeds – Second Edition**. John Wiley & Sons. (877) 762-2974; <http://www.wiley.com>

Newcomb, L. 1989. **Newcomb's Wildflower Guide**. Little, Brown & Co., Boston. <http://www.hachettebookgroup.com>

Uva, R.H., J.C. Neal, and J.M. Ditomaso. 1997. **Weeds of the Northeast**. Cornell University Press, (607) 277-2338 x 251; <http://www.cornellpress.cornell.edu>



**Pesticide Regulatory Agencies in New England, New York, and New Jersey****Connecticut Department of Environmental Protection**

Bureau of Materials Management & Compliance Assurance, Pesticide Management Program

79 Elm St.

Hartford, CT 06106-5127

Phone: 860-424-3369

Web: <http://www.ct.gov/dep>

*To search for pesticide products registered in Connecticut:*

<http://www.kellysolutions.com/ct>

**Maine Department of Agriculture**

Board of Pesticides Control

28 State House Station

Augusta, ME 04333-0028

Phone: 207-287-2731

Web: <http://www.maine.gov/agriculture/pesticides>

*To search for pesticide products registered in Maine:*

<http://state.ceris.purdue.edu/html/me.htm>

**Massachusetts Department of Agricultural Resources**

Pesticide Division

251 Causeway St.

Suite 500

Boston, MA 02114

Phone: 617-626-1778

Web: <http://www.mass.gov/agr/pesticides>

*To search for pesticide products registered in Massachusetts:*

<http://www.kellysolutions.com/ma>

**New Hampshire Department of Agriculture, Markets & Food**

Division of Pesticide Control

PO Box 2042

Concord, NH 03302

Phone: 603-271-3550

Web: [http://www.nh.gov/agric/divisions/pesticide\\_control](http://www.nh.gov/agric/divisions/pesticide_control)

*To search for pesticide products registered in New Hampshire:*

<http://state.ceris.purdue.edu/html/nh.htm>

**New Jersey Department of Environmental Protection**

Pesticide Control Program

PO Box 402

Trenton, NJ 08625-0402

Phone: 609-530-4070

Web: <http://www.nj.gov/dep/enforcement/pcp>

*To search for pesticide products registered in New Jersey:*

<http://www.kellysolutions.com/nj>

**New York State Department of Environmental Conservation**

Division of Solid & Hazardous Materials, Bureau of Pesticides Management

625 Broadway

Albany, NY 12233-7254

Phone: 518-402-8748

Web: <http://www.dec.ny.gov/chemical/298.html>

*To search for pesticide products registered in New York:*

<http://www.kellysolutions.com/ny>

**Rhode Island Department of Environmental Management**

Division of Agriculture, Pesticide Unit

235 Promenade St.

Providence, RI 02908-5767

Phone: 401-222-2781

Web: <http://www.dem.ri.gov/programs/bnatres/agricult>

*To search for pesticide products registered in Rhode Island:*

<http://www.dem.ri.gov/programs/bnatres/agricult/pesticide.htm>

**Vermont Agency of Agriculture, Food & Markets**

Division of Agricultural Resource Management & Environmental Stewardship,

Agrichemical Management Section

116 State St

Drawer 20

Montpelier, VT 05620

Phone: 802-828-2431

<http://www.vermontagriculture.com/ARMES/pest.htm>

*To search for pesticide products registered in Vermont:*

<http://www.kellysolutions.com/vt>

## **APPENDIX G    Useful Information**

### **In the event of accidental poisoning, contact:**

**1-800-222-1222**

(emergency hotline)

The Regional Center for Poison Control and Prevention  
Children's Hospital Boston  
300 Longwood Avenue  
IC Smith Building  
Boston, MA 02115

Administrative phone: 1-617-335-6609

Administrative fax: 1-617-730-0521

### **For emergency spill, fire, leak, or explosion:**

**1-800-262-8200**

Chemtrec ® 24-hour HAZMAT Emergency Communications Center  
<http://www.chemtrec.org>

**1-800-424-8802**

EPA National Emergency Response System

### **For pesticide information:**

**1-800-858-7378**

National Pesticide Information Center (NPIC)  
<http://www.npic.orst.edu>

EXTOXNET

The Extension Toxicology Network  
<http://extoxnet.orst.edu>

Greenbook®

<http://www.greenbook.net>

Crop Data Management Systems, Inc. (CDMS)

<http://www.cdms.net>