UMass Extension
CENTER FOR AGRICULTURE

BEST MANAGEMENT PRACTICES FOR SOIL & NUTRIENT MANAGEMENT IN TURF SYSTEMS

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.

Although the focus of the following text is lawn and landscape turf, much of the included information is also applicable to the management of other types of turf such as high value playing surfaces or very low maintenance turf areas.

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. UMass Extension's *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 at http://extension.umass.edu/turf/nutrient-management or in Appendix C of UMass Extension's *Best Management Practices for Lawn & Landscape Turf* manual (available online at http://extension.umass.edu/turf/publications-resources/best-management-practices).

The individual elements of a NMP are explained in greater detail in the rest of this document 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
• Provides information about growing conditions of soil • Informs additions of fertilizer and liming materials	• Provides information about behavior of soil • Helps in assessment of drainage characteristics and compatibility of amendments with existing soil

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).

Table 1. Interpretation of soil test categories

Categories	**Interpretation**
Very Low	Soil test level is well below optimum. Very high probability of plant response to additional nutrients. 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.
Low	Soil test level is below optimum. High probability of plant response to addition of nutrients. 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.
Optimum	For most plants, low probability of response to addition of nutrient. Most desirable soil test range on economic and environmental basis. 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.
Above optimum	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. Additional nutrient applications are not recommended.
Excessive	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. No P should be applied and steps should be taken to minimize losses from leaching and runoff.

The modified Morgan extractable nutrient values associated with each of the soil test categories for Massachusetts are summarized in Table 2. 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.

Table 2. UMass soil test categories for modified Morgan extractable nutrients.

	Very Low	*Low*	*Optimum*	*Above Optimum*	*Excessive*
P, ppm [a]	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

OBJECTIVE

Monitor soil pH regularly and manage it effectively with good liming practices.

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^{1+}) in soil solution. Active acidity is an indicator of current soil conditions.
- There are also acidic cations (H^{1+} and Al^{3+}) 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 ($CaCO_3$) 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) x 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) x 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
- low nutrient reserve - poor nutrient and moisture retention - potential for high nutrient losses via leaching	- generally more fertile - good nutrient and moisture retention - potential for significant content of unavailable nutrients

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.

OBJECTIVE	**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.**

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 3 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.

Table 3. Characteristics of some water soluble turfgrass fertilizers.

Fertilizer	Analysis (N-P-K)	Salt Index[a]	$CaCO_3$[b] 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 [c]	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 $CaCO_3$ (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.
c. A negative CCE increases pH; equivalent to applying 4 lbs. $CaCO_3$ for every 100 lbs. of calcium ammonium nitrate fertilizer, or 23 lbs. $CaCO_3$ 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 5 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 4 lists the most common synthetic WIN and SRN sources used by turf managers.

Table 4. Characteristics of some common slow release turfgrass fertilizers.

Fertilizer	Analysis (N-P-K)	Salt Index[a]	$CaCO_3$ Equiv. [b]	Lbs. Needed to Supply 1 Lb. N
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 $CaCO_3$ (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.

Table 5. Typical nutrient value and C:N ratio of several common organic and mineral soil amendments and nutrient containing materials.					
	Total N (%) [a]	**C:N ratio**	**Fraction of organic N made available first season** [b]	**P_2O_5 (%)**	**K_2O (%)**
Plant residues					
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 [c]	9	4	0.6-0.8	0	0
Animal products					
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 [d]	3-4	15	0.4-0.6	3	3
Compost (mature) [d]					
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
Mineral materials					
Potassium sulfate	0	-	-	0	50
Sul-Po-Mag	0	-	-	0	21
Wood ash	0	-	-	1	10
Colloidal rock phosphate [e]	0	-	-	25 [f]	0
Rock phosphate [e]	0	-	-	20-32 [f]	0
Granite dust [e]	0	-	-	0	3-5 [f]
Greensand [e]	0	-	-	1 [f]	4-9 [f]

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_4, which is immediately plant available; however, NH_4 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_2O and P_2O_5. These materials are extremely insoluble therefore available K_2O and P_2O_5 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).

Characteristics of readily-available (WSN) N sources:	Characteristics of slowly-available (SRN) N sources:
- provide a rapid increase in both color and growth rate - release of N is relatively independent of temperature, so can be used throughout most of the growing season with acceptable response - relatively rapid plant response rate - relatively short period of plant response (residual of 4 to 6 weeks at normal rates) - potential for surge shoot growth - can be applied in either granular or liquid form - high foliar burn potential (salt index) when applied at excessive rates or during periods of high temperature - greater potential for loss via leaching or volatility (gaseous losses) - generally less expensive per unit N when compared to many SRN sources	- release N slowly over a longer period of time than readily-available N sources - some sources are temperature dependent and do not release N in cold soils (< 55 °F) - in moist, warm summers nutrient release may be more rapid - low potential for foliar burn (salt index) - do not result in flushes of rapid growth (surge growth) - provide a longer residual plant response - potential carryover of N into the following growing season(s) - lower potential for gaseous loss and loss via leaching - relatively slow color response - generally cost more per unit of N when compared to WSN sources

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.

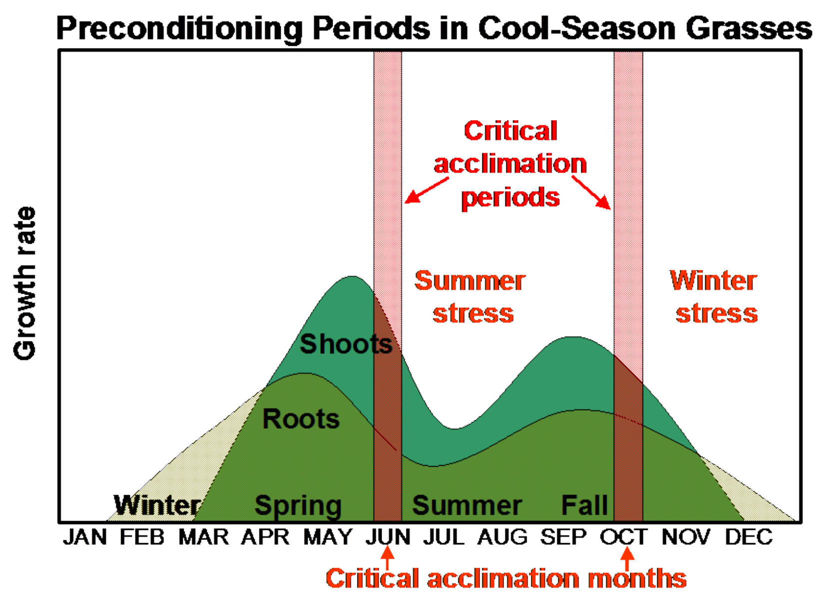
  Lower N rates may be possible where:

    - 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 6. 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.



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

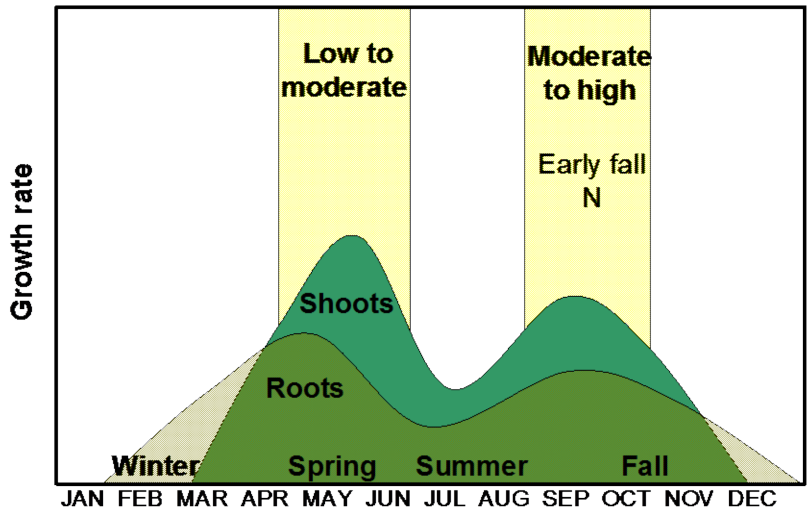


Table 7. Suggested options for timing, rate, and % SRN[a] for N applications[b] based on number of applications per year (lbs N/M = lbs of nitrogen per 1000 square feet).

	Number of N applications				
Time of year	**1x/yr**	**2x/yr**	**3x/yr**	**4x/yr [c]**	**4x/yr [c]**
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) [d]					25-50% SRN 0.75 - 1.0 lbs N/M
TOTAL ANNUAL N	**1.0 - 2.0 lbs N/M**	**2.0 - 3.0 lbs N/M**	**2.5 - 3.5 lbs N/M**	**3.0 - 4.0 lbs N/M**	**3.0 - 4.0 lbs N/M**

a. 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.
b. 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.
c. Programs utilizing 4 or more N applications per year are best suited for intensively used, high-value turf.
d. 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_2O_5 and K_2O, 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 1, '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 9, '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.

Table 8. Characteristics of common phosphorus containing fertilizer sources

Fertilizer	Analysis	Salt Index [a]	$CaCO_3$ Equivalent [b]	Lbs. needed to supply 1 lb. P_2O_5
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 $CaCO_3$ (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.

Table 9. UMass soil test phosphorus application guidelines.				
	Soil test phosphorus level			
	Very low	*Low*	*Optimum*	*Above Optimum*
	lbs P_2O_5 / 1000 sf / year			
Turf Establishment	2.0 – 2.5	1.0 – 2.0	0.5 – 1.0	0
Turf Maintenance	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 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 5 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 1, ‘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_2SO_4) is used in high-grade turf fertilizers because of its low burn potential (low salt index).

Table 10. Characteristics of common potassium containing fertilizer sources.				
Fertilizer	**Analysis**	**Salt Index** [a]	**$CaCO_3$ Equivalent** [b]	**Lbs. needed to supply 1 lb. K_2O**
Muriate of potash (KCl)	0-0-60	1.9	0	1.7
Sulfate of potash (K_2SO_4)	0-0-50	0.9	0	2.0
Potassium nitrate (KNO_3)	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 $CaCO_3$ (limestone) needed to neutralize the acidity of 100 lbs. of applied fertilizer.

Table 11. UMass soil test potassium application guidelines				
	Soil test potassium level			
	Very low	*Low*	*Optimum*	*Above Optimum*
Management level	lbs K_2O / 1000 sf / year			
Normal	3 – 4	2 – 3	1 – 2	0
Intensive [a]	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 5 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_2O_5 and K_2O
  - 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

--

The preceding was developed by:

- Mary Owen, *Extension Turf Specialist*
- Jason Lanier, *Extension Educator*
- Scott Ebdon, *Turf Agronomist*
- John Spargo, *Soil Scientist*

This text was excerpted from Section 7 of UMass Extension's *Best Management Practices for Lawn & Landscape Turf*: http://extension.umass.edu/turf/publications-resources/best-management-practices

UMass Extension

CENTER FOR AGRICULTURE

The UMass Extension Turf Program – http://extension.umass.edu/turf