Illinois Nutrient Research
& Education Council

Nutrient Management Practices

for Illinois Lawn Care Professionals

Table of Contents

Introduction

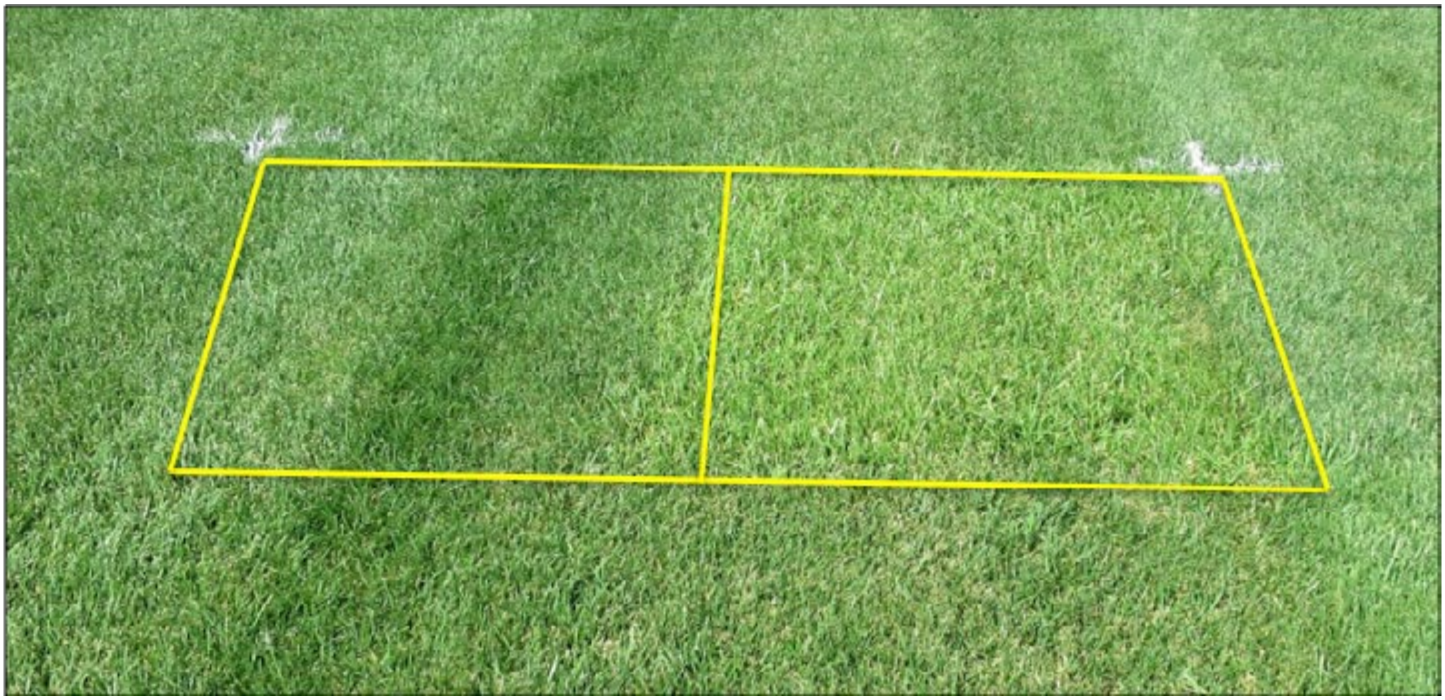
The cool-season turfgrasses grown in Illinois are incredibly resilient plants. These grasses withstand temperature ranging from less than -20ºF to greater than 100ºF, along with periodic drought and flooding, and still provide acceptable appearance and performance in home lawns, sports fields, and commercial landscapes. However, for best performance, these plants must be properly maintained and cared for. Proper management of cool-season turfgrasses will produce attractive, healthy lawns tolerant of normal use demands.

Factors that affect the best nutrient management practices include turfgrass species and cultivar selection and establishment, the use and age of the turf area, the growing environment (such as soils, precipitation, and light exposure), and cultural practices that include irrigation, clippings management, and fertilization.

Turf Species Selection & Establishment

Selecting and planting the most appropriate turfgrasses for the environmental conditions is an important first step. For example, sun-loving turf species, such as Kentucky bluegrass *(Poa pratensis)*, usually deteriorate and become thin when grown in shady conditions. This can occur as trees grow over time and create shade in a once sunny growing condition. Proper establishment procedures also play a critical role in long-term turfgrass performance. It has been reported that runoff on turfgrasses established on subsoils can be twice that of turf grown on topsoils and increase nutrient losses. Moreover, fine-textured subsoils often lack the oxygen necessary to promote good turf root growth. Finally, subsoils frequently exhibit higher pH and lower phosphorus availability to turf roots.

Nutrient uptake differs among turf species, as well as among cultivars of a species (Table 1). In fact, N-absorption differences among cultivars within turf species can be greater than between turf species. This does not mean turf managers must always know the identity of the turf species or cultivar when applying fertilizer, but it stresses that not all cultivars behave the same when supplied with similar amounts of nutrients. In a North Carolina study[1], Kentucky bluegrass uptake of nitrate-N varied by three-fold among the tested cultivars with 'Julia' averaging 56% greater nitrate-N uptake rate than 'Midnight' in both high and low N fertility concentrations. Despite this, differences



Contemporary turf-type tall fescue (left), Kentucky 31 tall fescue (right)

1 Zhang et al. Crop Sci (2013) 53:1179-1188.

in nutrient requirements between turf species must always be considered. For example, in a two-year Minnesota study[2], a Kentucky bluegrass blend was rated significantly lower in visual quality and higher in weed pressure than a tall fescue *(Schedonorus phoenix)* turf blend when both were fertilized at a low maintenance N rate of 2 lbs. per 1,000 ft^2.

Turfgrass Use & Age

The desired appearance and use of a turfgrass area will dictate the management level required to maintain quality. Most nitrogen (N) fertility recommendations are based on a desired level of maintenance ranging from low-to-high inputs. Older, mature lawns have had years of fertilizer applications and soil organic matter buildup from long-termed turf growth and often require less N than newly established and young lawns.

Growing Environment

Turf grown in shady conditions should be fertilized less than turf grown in full sun due to growth-rate differences. Shade-tolerant species require approximately half the nutrient application rate of turf grown in full sun, and it is recommended that no more than 2 lbs. N per 1,000 ft^2 per year be applied to shady areas. In fact, when higher N applications are made to shaded turf, the excess fertility can weaken the grass or create undesirable environmental conditions through leaching or runoff.

The soil in which a lawn is growing should be viewed as an "active" agent in the turfgrass environment. The physical, chemical, and biological properties of soils determine the movement, retention, and activity of nutrients, chemicals, and water. For example, when soils are coarse textured (sandy soils) and have low nutrient holding capacity (low CEC), retention of ammonium-nitrogen (NH_4^+) and potassium (K^+) is decreased. In these cases, the use of slow-release fertilizer sources or making light, frequent fertilizer applications (spoon-feeding) using quick-release fertilizers is recommended. Understanding these properties is essential to properly managing turfgrass nutrition and quality.

Cultural Practices

Returning mowed clippings to turf annually supplies approximately 1 lb. of N per 1,000 ft^2. Interestingly, it has been estimated that turf clippings store 25% to 60% of applied N, which can increase dry matter yields of Kentucky bluegrass and creeping red fescue *(Festuca spp.)* by 35% and perennial ryegrass *(Lolium perenne)* by 15%[3].

One of the most important turfgrass management activities is fertilization. Proper fertilization, along with proper mowing, are the most cost-effective means of achieving attractive and functional lawns in residential and commercial settings. As a basic and important tool in lawn management, fertilization contributes to turf color, density, uniformity, and growth rate. Moreover, when properly fertilized, lawns compete with weeds and recover from damage caused by environmental and biotic stresses more readily than improperly fertilized turf.

This guide provides the latest information on the best nutrient management practices for maintaining the quality of our cool-season Illinois and Midwestern turfgrasses.

TABLE 1

Amount of nitrogen (N) required each year for cool-season turfgrasses in Illinois

Turfgrass species	Annual recommended nitrogen application[a] (lbs. of N/1000 ft^2).
Creeping bentgrass *(Agrostis stolonifera)*	3-6
Fine fescues (creeping red, Chewings, hard, sheep) *(Festuca* spp.*)*	2-3
Perennial ryegrass *(Lolium perenne)*	3-4
Kentucky bluegrass *(Poa pratensis)*	3-4
Rough bluegrass *(P. trivialis)*	3-4
Tall fescue *(Schedonorus phoenix,* formerly *Festuca arundinacea)*	3-4

[a] Use the high rangeof rates for turf grown in infertile soils, when clippings are removed from the site, and in high traffic areas. Lower rates can be used for turf grown in inherently fertile soils and when clippings are returned to the turf.

2 Miller et al. HortTechnology (2013) 23(5):610-612.
3 Kopp and Guillard, Crop Sci. (2002) 42:1225-1231.

Essential Nutrient Requirements for Turfgrass

Like other plants, turfgrasses require 16 essential nutrients for proper growth and development. Several of these nutrients; carbon, hydrogen, and oxygen, are derived from the carbon dioxide, oxygen gas, and water supplied by the growing environment. The other essential nutrients should to be routinely monitored and applied to ensure proper plant health and quality. The nutrients required in relatively large amounts are referred to as "macronutrients" and those required in smaller quantities are referred to as "micronutrients" (Table 2).

Nutrients are taken up by turfgrass roots as either positively or negatively charged (ionic) forms that result from fertilizer compounds being dissolved into the soil-water solution. Turfgrass foliage can also absorb small quantities of nutrients (primarily micronutrients), although this is not a common lawn fertilizer application method with the exceptions of iron and manganese where quick greening of the turf is desired. The mineral nutrient electrical charge greatly determines its behavior and movement in soils (Table 2). Soils possess a net negative charge, and therefore, negatively charged nutrients in the soil-water solution will be repelled with some possible loss due to leaching into the soil profile below the root system. Positively charged nutrients in the soil solution will be attracted to soil particles and held in reserve adding to the soil's cation exchange capacity (CEC). Generally, the more clay particles (fine texture) in a soil, the higher the CEC, and conversely, the greater the sand content (coarse texture), the lower the CEC with less nutrients held in the soil.

During new urban development, vegetation and topsoil are often removed during the construction process, with only a few inches of topsoil commonly returned to residential sites and placed directly on high clay-content subsoils. Even though the fine textured clay subsoils have high CECs, these soils are often compacted and poorly aerated and aggregated. To maintain quality, turfgrass planted in these new residential developments often require greater nutrient inputs than do established sites.

Once inside the plant, a nutrient can either be moved to where it is needed (termed "mobile"), or incorporated into tissue structures shortly after uptake ("immobile"). A nutrient's mobility inside plants is often used to visually

TABLE 2

The 16 essential nutrients for turfgrass growth and development and the ionic form taken up by turf roots

Nutrient and Chemical Abbreviation	Available Form in the Soil Solution
Macronutrients	
carbon (C)	CO_2; HCO_3
hydrogen (H)	H_2O; HCO_3^-; NH_4^+
oxygen (O)	O_2; H_2O; HCO_3^-; NO_3^-; CO_2; SO_4^{2-}
nitrogen (N)	NO_3^-; NH_4^+
phosphorus (P)	$H_2PO_4^-$; HPO_4^{2-}
potassium (K)	K^+
calcium (Ca)	Ca^{2+}
magnesium (Mg)	Mg^{2+}
sulfur (S)	SO_4^{2-}
Micronutrients	
iron (Fe)	Fe^{2+}; Fe^{3+}
manganese (Mn)	Mn^{2+}
zinc (Zn)	Zn^{2+}; $ZnOH^+$
boron (B)	H_3BO_3
copper (Cu)	Cu^+; Cu^{2+}
molybdenum (Mo)	MoO_4^{2-}
chlorine (Cl)	Cl^-

identify deficient elements based on the location of the symptoms. Nitrogen, phosphorus, potassium, magnesium, and chlorine are mobile in plants and exhibit deficiency symptoms on older growth (tissues) first. Thus, when unavailable from the soil, these nutrients can be moved from older tissues and relocated to new growing points. Calcium, iron, and manganese are immobile nutrients in plants and exhibit deficiency symptoms on new growth or growing points first. Because these elements cannot moved from older tissues, the deficiency is exhibited in new growth. Sulfur, zinc, copper, molybdenum, and boron are "somewhat mobile" nutrients that behave similarly to immobile nutrients.

Plants are not able to take up all forms of mineral nutrients. For example, turfgrasses take up nitrogen in the nitrate (NO_3^-) or ammonium (NH_4^+) forms, but are unable to take up the elemental nitrogen that comprises more than 75% of the Earth's atmosphere. See Table 2 for the 16 essential plant nutrients, the chemical symbol of each, and the forms taken up by turf plants.

Macronutrients

The mineral nutrients that turfgrasses require in relatively large quantities, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur, are called macronutrients. In some references, nitrogen, phosphorus, and potassium are called primary macronutrients, and calcium, magnesium, and sulfur, secondary macronutrients.

Nitrogen

Nitrogen (N) is commonly applied to turfgrass to improve color, density, root growth, stress tolerance, carbohydrate reserves, and recuperative potential. Among these characteristics, increasing carbohydrate reserves for survival during dormant periods, turf regrowth, and stress tolerance is important for cool-season lawns because carbohydrates are depleted during the peak growth period in the autumn and can leave turf plants more susceptible to winter injury and slow to green up in spring. As nitrogen fertility is increased from very low to medium levels, carbohydrate levels rapidly increase in plant tissues. However, as nitrogen fertility is increased to very high levels, carbohydrates are primarily used for leaf and shoot growth, and none are stored in reserve.

Healthy turf tissues contain more nitrogen than any other mineral, and thus, it is the most important element in turfgrass culture (Table 3). Nitrogen is found in chlorophyll (a green pigment in turf leaf cells necessary for photosynthesis), and some plant proteins, amino acids, enzymes, and vitamins. Nitrogen uptake is demand-driven, that is, differences in plant growth rates will influence nitrogen uptake. Nitrate-nitrogen (NO_3^-) is the most common form of nitrogen taken in by turf plants, with ammonium-nitrogen (NH_4^+) also being absorbed. It has been stated that nitrate-N "will grow turfgrass," while ammonium-N "will green turfgrass". However, unusually high levels of ammonium-N can be toxic to plants. Response to nitrogen fertilization can be quick; N can move into leaf tissue within 15 to 24 hours of application under good growing conditions.

Nitrogen sufficiency levels in turfgrass clippings have been reported to range from 2.7% to 3.5% dry weight (Table 3). However, turfgrass species differ in nitrogen sufficiency. For example, nitrogen sufficiency levels of 3.2% to 4.6% dry weight for Kentucky bluegrass clippings and 2.8% to 4.2% dry weight in tall fescue have been reported. In addition, recent research has found that to maintain quality, tall fescue required approximately 90% of the nitrogen fertility amounts of Kentucky bluegrass.

TABLE 3

Elemental content (in percent) in cool-season turfgrass leaf tissues following tissue analysis

Turfgrass Species	% Nitrogen	% Phosphorus	% Potassium	% Calcium	% Magnesium	% Sulfur
Creeping bentgrass	2.40 - 8.30	0.20 - 0.63	2.20 - 2.60	0.21 - 0.98	0.22 - 0.35	0.23 - 0.43
Kentucky bluegrass	2.51 - 5.40	0.27 - 0.49	1.73 - 3.08	0.27 - 0.58	0.13 - 0.32	0.18 - 0.24
Perennial ryegrass	3.34 - 5.10	0.35 – 0.55	2.00 – 3.57	0.25 – 0.70	0.16 – 0.32	0.27 – 0.56
Tall fescue	3.40 – 5.40	0.34 – 0.51	3.00 – 4.00	0.40 – 0.49	0.24 – 0.35	0.40 – 0.44
Creeping red fescue	3.70	0.34	2.62	0.39	0.24	no data
Average of cool-season spp.	4.00 – 5.00	0.41 - 0.48	2.10 – 3.60	0.39 – 0.69	0.23 – 0.31	0.21 – 0.42

Adapted from Mill and Jones, Jr. *Plant Analysis Handbook II* (1996), MicroMacro Publishing.

How Much Nitrogen?

Although soil nitrogen levels can be determined by soil tests, it is difficult to plan a N fertility program based only on test results. Thus, this guide (Table 4) encompasses the entire growing season. Application rates are indicated within a range because of differences in turf species, climate, soils, cultural practices, and/or desired lawn quality.

Nitrogen needs are variable. Generally, most lawns require 2 to 4 lbs. of actual N per 1,000 ft^2 per year, with at least half or more applied after September 1. Table 3 outlines conditions that should be considered when determining nitrogen application rates.

Additional considerations include the burn and leaching potential of the N source. Burn potential is essentially an indication of the fertilizer's potential to pull water out of the turf plant by creating a high salt concentration in the soil. Quick-release nitrogen fertilizers are prone to causing burn because the minerals are in a salt form and are highly soluble in the soil-water solution. Certain environmental conditions, such as high temperatures and low humidity can increase a fertilizer's burn potential. Fertilizer burn potential is reduced by applying no more than 1 lb. of actual N per 1,000 ft^2 per application.

Nitrogen Deficiency Symptoms

Lawns in need of nitrogen can exhibit common symptoms. At first, older turf leaves at the base of the plant will typically become light green as nitrogen in these leaves moves into younger foliage. Without applying nitrogen, the older leaves become yellow, then yellow-brown, and finally die. Under extreme conditions, leaf blades can die starting at the tip. Moreover, while pale-green turf is a common visual symptom, additional conditions such as poor turf density; weed invasions; and/or the presence of dollar spot, rust, or red thread diseases can also indicate a need for N. In addition, lawns under-fertilized with N grow slowly and produce fewer roots, leaves, and tillers. Finally, turfgrasses can exhibit decreased cold (winter) tolerance, because reduced nitrogen fertilization can restrict potassium uptake, even though adequate K levels are present in the soil. Overall, poor lawn color, density, and growth rate, as well as the presence of certain diseases, can be used to determine the need for nitrogen fertilization.

Nitrogen Excess Symptoms

Lawns receiving excessive applications of nitrogen are commonly dark green, succulent, and have spindly leaf growth. In addition, some turf diseases (e.g., *Pythium* blight, some patch and/or leaf spot diseases), as well as excessive thatch production and increased water use, and mowing requirements, can result from excessive applications of nitrogen. Less obvious problems include reduced root, rhizome, tiller, and stolon growth, as well as reduced heat and drought tolerance. Finally, excessive application of ammonium-N fertilizers can reduce potassium uptake.

TABLE 4

General conditions that can affect N fertilization levels

Higher N Requirements	Lower N Requirements
High quality expectations	Low quality expectations
Kentucky bluegrass, perennial ryegrass, tall fescue, creeping bentgrass	Fine-leaf fescues (creeping red, Chewings, sheep, and hard fescues)
New lawns	Old, established lawns
Clippings collected	Clippings returned to turf
Well–drained or sandy soils	Heavy soils
Highly trafficked	Minimally trafficked
Irrigated	Non-irrigated
Wet growing season	Dry growing season
Long growing season	Short growing season

Nitrogen Forms

Turf nitrogen fertilizers can be classified as “quick release” or “slow release”. Quick-release forms contain urea, nitrate, and/or ammonium and include urea, ammonium phosphate, ammonium sulfate, and calcium nitrate (Table 5). Generally, these fertilizers release nitrogen into the soil-water solution rapidly with rainfall or irrigation and produce a relatively short-lived flush of growth, perhaps lasting 4 to 6 weeks. These fertilizers can also burn turf leaves if incorrectly applied and are more prone to leaching than slow-release materials. Thus, in programs relying heavily on quick-release fertilizers, light, frequent applications are recommended. On the other hand, however, based on the actual nutrient costs, these fertilizers are usually cheaper per pound of nitrogen than slow-release forms. In the past, ammonium nitrate, a quick release nitrogen source, was widely used in turf management. Presently, because of concerns regarding its use in explosives, ammonium nitrate is used less in turf management due to limited availability.

Most quick release nitrogen sources are in a soluble form that can be leached or moved below the turf root zone, which potentially creates an environmental problem due to groundwater contamination. While not a great problem in many Illinois regions, potential problems can occur when turf is grown on sandy soils, over a shallow water table, or whenexcessive amounts of soluble forms of nitrogen have been applied.

Slow-release forms of nitrogen include natural organic materials such as activated sewage sludge and animal by-products, synthetic organic materials such as isobutyldiurea IBDU and ureaform (UF), and coated materials such as sulfur-coated urea (Table 6). These materials release nitrogen over a period of time, perhaps as long as 12 to 16 weeks. Slow-release nitrogen fertilizers less likely to leach or burn turf than quick-release N fertilizers, but the slow-release fertilizers commonly cost more per pound of actual N than quick-release fertilizers. In addition, nitrogen release to new lawns, may be too slow to produce the desired turf development, or may take several years of application to build N release that achieves the desired season-long health and quality. Lawn care managers must weigh the advantages and disadvantages of quick and slow-release nitrogen fertilizers, and in many cases combining both forms of N fertilizers, when planning a turf management program.

Natural organic materials, including biosolids and activated sewage sludge, manures, and poultry and fish products, are broken down slowly by microorganisms in the soil. Nitrogen levels are usually low (commonly less than 10% by weight) and N-release rates are usually slow. Temperature, oxygen levels, moisture, and pH levels affect the activity of these microorganisms and, thus, the rate of nitrogen release. For example, cold soils in spring and fall can slow microorganism activity and the rate of nitrogen release of these fertilizers. Before using these materials, turf managers should consider the percent nitrogen, odor characteristics, and application timing. Also, because high levels of soluble salts in some fresh natural organic materials can damage turf, be sure the products are fully composted prior to application.

There are a number of commercially available ureaformaldehyde (UF) products with nitrogen percentages ranging from 35% to 40%. Nitrogen availability in these fertilizers is comprised of three fractions, with a portion soluble in cold water and readily available, a portion soluble in hot water and less readily available, and a third portion insoluble in either cold or hot water and very slowly available (taking longer than 7 months for nitrogen release). Like

TABLE 5

Quick-release nitrogen carriers

Carrier	analysis[a]	% total N	% phosphate	% soluble potash
urea	46-0-0	46	0	0
ammonium nitrate	33-0-0	33	0	0
ammonium sulfate	21-0-0	21	0	0
calcium nitrate	16-0-0	16	0	0
potassium nitrate	13-0-44	74	0	45
monoammonium phosphate	11-52-0	11	52	0
diammonium phosphate	18-46-0	18	46	0

[a] The fertilizer analysis is the percent nitrogen, phosphate, and potash by weight in a fertilizer package.

natural organics, nitrogen release is dependent on soil microorganism activity and is limited during cool seasons; it may be necessary to use water-soluble N carriers for spring and fall applications to supplement the N availability of ureaform products.

Related to ureaformaldehyde products are fertilizers made with larger amounts of urea and less formaldehyde; methylene ureas (MU) and methol ureas fall into this category. Nitrogen release is usually faster than with ureaformaldehyde products, and while more expensive per actual pound of N than urea or ammonium nitrate, burn potential is less.

Due to low water solubility, isobutyldiurea (IBDU) releases nitrogen slowly. The release rate increases as the temperature rises, but nitrogen release at low temperatures is less effected than when using slow-release N products that rely on microbial activity for release. Moreover, soil moisture levels and granule size can effect nitrogen release with faster N release in wet soils than in dry soils and when small granules are applied compared to larger granules.

Coated fertilizers include sulfur-coated urea (SCU) and polymer-coated nitrogen. Sulfur-coated urea contains 32% to 38% nitrogen and use sulfur, often followed by a sealant, to encapsulate the urea. The release rate increases as the coating thickness decreases, temperatures rise, and the fertilizer prills (a solid fertilizer pellet or globule formed by the solidifying of a liquid) are damaged by age or rough handling. Since urea particles are not coated evenly, SCU is approximately one-third quick release and two-thirds slow release. This gives the advantage of initial response to application combined with additional slow-release, long-term benefits.

Polymer-coated nitrogen fertilizers use plastic (polymer) to coat urea, SCU (polymer-coated sulfur-coated urea or PSCU), or other nitrogen forms; the N release rate is controlled by the composition and thickness of the polymer and increases when temperatures are higher.

Stabilized Nitrogen Sources

When nitrogen is applied as urea, there are several transformations that take place in the soil that convert urea N to nitrate N. Nitrogen stabilization technologies are applied to urea fertilizers to inhibit or slow this natural conversion. In one of these technologies, the product slows the conversion of urea to ammonia (an intermediate step in urea to nitrate conversion), which reduces ammonia volatilization and allows greater amounts of nitrogen to be available to the turf. The second technology, targets the bacteria *(Nitrosomonas spp.)* that converts ammonium to nitrite (another intermediate step in urea to nitrate conversion), slowing the conversion to nitrate. Once in the nitrite form, nitrogen is converted to nitrate, a form of N plants can use, but also a N form that leaches readily. Ammonium nitrogen is less likely to leach than nitrate N, allowing greater amounts of N to be available to the turf.

Applying Nitrogen Fertilizers to Lawns

Nitrogen fertilizer sources can be combined over an annual fertility program. For instance, early September and late October/early November applications can use quick-release nitrogen sources, while early May and late June applications can use slow-release forms.

When selecting nitrogen fertilizers for a specific application, consider the budget, how quickly and how long a response is desired, the amount of mowing and irrigation required, and the nitrogen form that will best fit into this program.

TABLE 6

Slow-release nitrogen carriers

Carrier	% Nitrogen
isobutyldiurea (IBDU)	31
sulfur-coated urea (SCU)	32 to 41
polymer-coated nitrogen (PCU)	39 to 44
polymer-coated sulfur-coated urea (PSCU)	39 to 40
methylene ureas & ureaformaldehyde	38
activated sewage sludge	4 to 6
manures	variable
poultry and fish products	variable

Phosphorus

Phosphorus (P) is essential for root growth and branching, drought tolerance, water-use efficiency, and seedling establishment and is involved with holding and transferring energy required by turfgrass plants for metabolic processes. Despite these important functions, the elemental phosphorus content of grass tissue is relatively small (0.3% to 0.55% dry weight) compared to the other macronutrients. Penn State University research found that at least 1.4 lbs. of plant-available phosphorus per 1,000 ft^2 is required for normal turf growth and development.

Phosphorus is immobile in soils and can accumulate in turfgrass tissue at 100 to 1,500 times the concentration in the soil solution due to active uptake (roots expend energy for its uptake) and great mobility in plant tissue. The most important factors affecting phosphorus availability in turf soils are soil pH and the concentrations of iron, aluminum, manganese, and calcium. When the soil pH is below 5.5, phosphorus becomes unavailable and causing deficiencies in turfgrass. In acidic soils with pH below 5.5, iron and aluminum in the soil solution bind with phosphorus, making it unavailable for root uptake. In alkaline soils with pH above 8.0, phosphorus availability is reduced because it binds with calcium to form calcium phosphates. Subsoil conditions in urban developments frequently lack enough phosphorus for rapid turfgrass establishment and vigorous growth of mature turf. Therefore, maintaining soil pH between 6.0 and 7.0 ensures maximum phosphorus availability for turf.

Phosphorus Deficiency Symptoms

Phosphorus deficiency in turfgrass is likely to occur when the available soil phosphorus levels are low, during establishment when root growth is limited, during cool spring periods when root growth is slow, and under elevated soil pH conditions. Phosphorus deficiencies in Illinois are rare, but can occur. Initially, older, lower leaves become dark and then dull blue-green resembling drought stress. Turfgrass foliage will become reddish-purple, starting from the tip and margins of leaf blades (especially apparent in cool weather), and exhibit overall poor growth. Sod will be slow to knit. Tall fescue leaves can become cupped.

Phosphorus Excess Symptoms

Excessive phosphorus often appears as micronutrient (zinc, iron, or cobalt) deficiency. Excessive phosphorus can cause iron to become insoluble and unavailable for uptake and high phosphorus also interferes with nitrogen absorption.

Base phosphorus applications on soil tests using the guidelines in Table 7 to determine the application rates for buildup to a desirable soil-test level. Soil tests should be made before new turf is seeded, and every few years on established turf, to ensure that available soil phosphorus is present in adequate amounts. Be aware that high phosphorus soil levels increase the potential for annual bluegrass (*Poa annua*) infestation on highly maintained turf.

Fertilizer phosphorus is obtained primarily from rock phosphate ores or organic fertilizers. It is most commonly applied to turf as triple super phosphate (0-46-0, or 46% phosphate), monoammonium phosphate ($NH_4H_2PO_4$; 11-50-0, or 11% nitrogen and 50% phosphate), or diammonium phosphate ($(NH_4)_2HPO_4$; 18-46-0, or 18% nitrogen and 46% phosphate).

TABLE 7

Recommended P_2O_5 applications[a], based on Bray P1 Extractable Phosphorus soil test

P1 soil test (lbs./acre)	P_2O_5 (lbs./1,000 sq. ft.)[b]
Less than 25	4
25 to 50	2
50 to 70	1
More than 75	0

[a] Usually, one application of a complete fertilizer (12-12-12, 10-6-4, etc.) per year is enough to maintain a sufficient level of phosphorus in the soil for turfgrass growth.

[b] If the recommendation exceeds 2 pounds of P_2O_5 per 1,000 square feet, split the applications between spring and fall—except when the fertilizer is to be incorporated into the soil.

Potassium

Potassium (K) is associated with disease resistance, cold and heat tolerance, improved stress and drought tolerance, internal water management, and wear tolerance; it is second to nitrogen in the amounts required for turf growth. Potassium is absorbed by plants in the K^+ form.

Potassium is mobile in plant tissue (can be moved around inside the plant to where it is needed), and can be taken up in amounts greater than is required for proper growth and development. Often referred to as "luxury consumption", excessive uptake is considered an inefficient use of potassium. In fact, there are reports of turf managers annually applying 2-3 times more potassium than nitrogen in an attempt to stimulate stress tolerance and strengthen leaves to improve traffic tolerance. However, research demonstrates that optimal turfgrass stress tolerance occurs when soil potassium is maintained at a level that produces sufficient tissue K concentrations. In addition, excessive potassium application can contribute to salinity stress, decrease the uptake of calcium, magnesium, or manganese, and promote greater incidence of snow mold diseases.

Potassium Deficiency Symptoms

Turf leaves can droop (become flaccid), followed by interveinal yellowing of older leaf tips. Yellowing will progress to the entire leaf, except for the green midvein. Severe deficiency will lead to browning and death of leaf tips and margins, which gradually extend down to the leaf base. Potassium-deficient turf often exhibits reduced turf density, early wilting during drought, and reduced resistance to disease and cold injury.

Potassium Excess Symptoms

Very high potassium levels can interfere with nitrogen and magnesium uptake, causing these macronutrients to be deficient.

As with phosphorus, potassium applications should be based on soil tests. To maintain adequate soil levels of potassium, apply K-containing fertilizers, return clippings after mowing, and avoid overwatering to reduce leaching losses.

If clippings are removed, larger and more frequent applications of potassium will be required to maintain satisfactory growth, usually about half the rate at which nitrogen is applied. Where clippings are returned to the lawn, potassium applications should be approximately 2 to 2.5 lbs. per 1,000 ft^2 per year. Through leaching, sandy soils tend to lose potassium more rapidly than finer-textured soils, and K reserves can be difficult to build up in sandy soils. Thus, small, frequent potassium applications are recommended on coarse-textured soils. Table 8 provides a guide for determining the desired rates of application to build up potassium to a more desirable soil-test level.

Winterizer fertilizers often contain large amounts of potassium as potash, implying that autumn applications of these fertilizers will benefit lawns during the winter. Potash certainly plays a role in turfgrass cold tolerance, but is also important at other times of the year, and maintaining adequate potash levels throughout the growing season is recommended.

Fertilizer potassium is derived from potassium mines as the salt potassium chloride (KCl), also called muriate of potash or just potash. Muriate of potash, when used as a fertilizer, has an analysis of 0-0-60 (60% K_2O). Potassium nitrate (KNO_3; 13-0-44, 13% N and 44% K_2O) and potassium sulfate (K_2SO_4; 0-0-50, 44% K_2O and 18% S).

TABLE 8

Recommended potash applications based on soil tests[a]

K soil test (lb./acre)	Potash[b] (lb./1,000 sq. ft.)
Less than 50	6
50 to 100	4
100 to 150	2
150 to 200	1
More than 200	0

a Potash may be applied as 0-0-60 (muriate of potash) or as a complete fertilizer.

b Applications should be split into 1.5-pound increments applied through the growing season since rates of more than 1.5 lbs. per 1,000 square feet may cause burning. Apply to dry turf and water immediately if possible.

Calcium, Magnesium, & Sulfur

Most Illinois soils have adequate quantities of the secondary macronutrients calcium, magnesium, and sulfur for turf growth, and even though deficiency and excessive symptoms are rare, they can occur in turf growing on acidic soils (< 5.5 pH), sandy soils, soils high in sodium (Na^+), soils from which these minerals have leached out of the rootzone, or when clippings are removed (Table 9). Of these macronutrients, sulfur is the most likely to be deficient, especially in infertile sandy soils or soils low in organic matter (Table 10). Sulfur is commonly supplied to turf during the breakdown of soil organic matter and during precipitation in areas where sulfur-containing coal is burned. When thought to be deficient, apply 4 ounces of elemental sulfur (99% sulfur) to a 1,000 ft^2 test area for evaluation. Should deficiency symptoms be eliminated, apply 4 ounces of elemental sulfur per 1,000 ft^2 over the remaining turf area. Sulfur can also be supplied to turf as gypsum ($CaSO_4$; 18.6% sulfur), ferrous sulfate ($FeSO_4$; 18.8% sulfur), potassium sulfate (K_2SO_4; 17.6% sulfur), and ammonium sulfate ($(NH_4)_2SO_4$; 24% sulfur).

TABLE 9

Conditions which favor macronutrient deficiency conditions

Macronutrient	Condition which promotes deficiency
Nitrogen	Sandy soils; high leaching conditions from rainfall and irrigation; low soil organic matter; clipping removal; loss by denitrification under anaerobic conditions such as waterlogged or compacted soils; soil pH<4.8 will inhibit nitrification; infertile soils
Phosphorus	Sandy soils; low CEC irrigated soils; soil pH<5.5 will cause Fe, Al, Mn to bind with P; soil pH>8.5 will cause Ca to bind with P; soils high in clay content; clipping removal; turf grown on subsoil or infertile soil
Potassium	Deficiency most likely under high rainfall or leaching from irrigation; sandy or low CEC soils; clipping removal; sites receiving high applications of Ca, Mg, or Na; excessive N applications
Calcium	Deficiency most likely under acidic (pH<5.5) conditions on low CEC soils; high leaching conditions; true deficiencies most probable in the roots rather than the shoots
Magnesium	Deficiency most likely under acidic (pH<5.5) conditions on sandy or low CEC soils; high leaching conditions
Sulfur	Deficiency of S is associated with soils low in organic matter; sandy or low CEC soils; high rainfall and leaching; high N additions with clipping removal

Adapted from Carrow et al., *Turfgrass Soil fertility and Chemical Problems* (2001), Sleeping Bear Press.

TABLE 10

Secondary macronutrient deficiency and excess symptoms in turfgrass

Macronutrient	Deficiency Symptoms	Excessive Symptoms
Calcium	Rare. Reddish-brown coloration along the margins of younger leaves, eventually extending to the midvein. Foliage color will fade to a light red or rose-colored red and leaf tips will wither.	Interferes with magnesium absorption. High Ca usually causes high pH, which in turn creates micronutrient deficiencies.
Magnesium	Green or yellow-green stripes on older leaf blades, changing to a reddish color under extreme deficiency. Increased winter injury.	Rare, but can interfere with calcium and potassium uptake.
Sulfur	Similar to nitrogen and potassium deficiency. Pale-green to yellow discoloration of the older, lower leaves which will progress to gradual burning of the leaf blade starting at tip.	Rare in soils and with granular S fertilizer, but liquid S fertilizer have the potential to burn foliage when applied at rates >2 to 5 lbs. product per 1,000 ft^2.

Adapted from Beard, *How to Have a Beautiful Lawn* (1983), Beard Books.

Micronutrients

The essential micronutrients required by turfgrasses are iron (Fe), manganese (Mn), zinc, (Zn), boron, (B), copper, (Cu), molybdenum (Mo), and chlorine (Cl). Turfgrasses require micronutrients in very small quantities that are often supplied as impurities in synthetic or organic fertilizers, returned clippings, liming and topdressing materials, some pesticides (especially fungicides), and irrigation water. Micronutrient deficiencies in sandy soils can be corrected by adding soil or organic matter to the rootzone.

Unless the soil texture is extremely sandy or the pH is greater than 7.5, micronutrient deficiencies in Illinois lawns are rare (Figure 1). For example, even though iron may not be deficient, applications can enhance the color of various turfgrass species, but with fewer negative consequences than excessive application of nitrogen especially during hot weather. Iron is an abundant component in soil minerals and is generally available in adequate amounts when soils are acidic, but less so when alkaline. Most iron added to alkaline soils is immediately rendered unavailable due to soil chemical reactions and may not result in the enhanced green color response on high pH soils. However, studies report that iron fertilization can enhance turf growth and quality under acidic pH conditions. Along with green color enhancement, application of iron to Kentucky bluegrass has also been reported to enhance root growth.

Iron is the micronutrient most often deficient in turf, and Fe deficiencies can be problematic when soil pH levels are above 7.5 and phosphorus levels are high. To correct iron deficiency, apply 1 to 2 ounces of ferrous sulfate per 1,000 ft^2 of turf every two weeks.

Deficiencies of other micronutrients are not common in turf, but high soil pH is also known to induce deficiencies of manganese, zinc, or copper in other crops. High soil phosphorus, in conjunction with high pH, can further aggravate a zinc deficiency.

Micronutrient Deficiency Symptoms

Turfgrass micronutrient deficiencies are rare. Conditions in which turfgrass micronutrient deficiencies occur are coarse

FIGURE 1

General trends of soil pH on nutrient availability and various turf problems

	5.0	5.5	6.0	6.5	7.0	7.5	8.0
	Deficiency (<5.5) Nitrogen, Phosphorus, Potassium, Magnesium, Molybdenum, Sulfur					**Deficiency (>7.5)** Phosphorus, Iron, Manganese, Boron, Copper, Zinc	
	Disease (>5.3) Spring dead spot		**Disease (<6.0)** Summer patch	**Disease (>6.5)** Pink snow mold, Take-all patch			
Al, Mn toxicity (<5.0)	Thatch accumulation (<5.5)					N (urea) volatilization (>7.5)	

Adapted from Baird, Green Sect Rec (2007) 45(5):1-8.

textured or sandy soils, elevated soil pH, and clipping removal. Overall, micronutrient deficiency will cause turf yellowing and a decreased growth rate, but deficiency symptoms of individual micronutrients may differ (Table 11).

Micronutrient Excess Symptoms

The availability of micronutrients is closely linked to soil pH conditions. When soil pH is low or very acidic (pH<4.5), micronutrients previously bound up in the soil can become available for plant uptake, producing excessive or toxic conditions. Micronutrient toxicity can also be produced by misapplication of fertilizers containing these elements. For example, excessive iron can potentially blacken leaves, create tissue injury, and induce manganese deficiency.

TABLE 11

Micronutrient deficiency symptoms in turfgrass

Micronutrient	Deficiency symptom in turfgrass
Iron	Interveinal yellow discoloration (chlorosis) of younger leaves which will progress to older leaves under severe deficiency. Turfgrass plants will become spindly and weak, and the entire lawn can appear spotted, with some areas exhibiting deficiency, while other areas do not.
Manganese	Reduced shoot growth rate. Interveinal yellow discoloration with small distinct greenish-gray spots developing on lower parts of the leaf, eventually progressing to the leaf tip. Leaf tip may turn grey or white and droop and wither. The lawn may appear mottled.
Zinc	Chlorotic leaves with some mottled. Shoot growth will become stunted and young leaves will become thin, shrivel, and dry up.
Copper	Yellowing and chlorosis of leaf margins of youngest to middle leaves. A bluish color will appear at the tips of the youngest leaves and tissue death will progress from the tip to the leaf base. Leaves may roll or twist.
Boron	Young leaves exhibit leaf tip chlorosis followed by interveinal chlorosis of young and older leaves. Shoots will become discolored and stunted and leaves will develop a stubby, rosette pattern with streaks of dead tissue in the interveinal areas.
Molybdenum	Similar to nitrogen deficiency. A pale green to yellow mottled discoloration of the older, lower leaves in the interveinal areas and progress to dead spots and tissue withering.

Adapted from Beard, *How to Have a Beautiful Lawn* (1983), Beard Books.

Behavior of Nutrients in Turfgrass Soils

Current growing conditions in Illinois vary; prior to settlement, approximately 60% of Illinois was covered by prairies with the remainder by forests. In general, prairie soils were naturally fertile, while the forest soils less so. Since the 1850s, with little exception, the prairies have been converted to row-crop production and/or urban development, which has altered the natural fertility of the soil. Some forested areas have also been developed, which also changed the natural fertility. Moreover, the changes in soil fertility were not uniform, particularly where urban development has occurred. Often, following development, homeowners are left with thin layers of topsoil and low quality subsoils for growing lawns. In best-case scenarios, proper turf fertilization is handled on a lawn-by-lawn basis because of variable soil fertility.

Healthy turf develops a dense aboveground and belowground mass of shoots and roots that protect soils from erosion and chemical and pollutant movement and runoff. Additionally, high microbial activity in turf-covered soil has the potential to degrade organic chemicals relatively rapidly, which can improve runoff water quality and reduce groundwater contamination. In fact, studies[4] have shown that turfgrass controls the amount of water runoff and improves runoff water quality more effectively than other land uses or ground covers.

The alteration of soil structure, hydrology, and landscape ecology can contribute to nutrient runoff in urban turf plantings. During urban development, the existing vegetation is commonly removed, topsoil is stripped exposing subsoil, and soil aeration and hydrology are altered due to soil compaction during construction. Subsoil is inherently low in essential plant nutrients and contains large amounts of clay with small, water-filled pores and limited large, oxygen-filled pores. Thus, turf growing on “urban soils” often requires large amounts of external inputs to maintain quality. A 2014 Ohio study[5] of tall fescue turf found that runoff initiation from a simulated rain event occurred twice as fast on turf established on subsoil than turf established on topsoil, and the amount of runoff was four times greater from subsoil than from turf growing on topsoil. In the same study, although nitrogen, phosphorus, potassium, and sulfur losses in runoff were low, there was significantly higher nutrient loss from subsoil-grown lawns than from topsoil-based lawns and there was more nutrient loss from application of inorganic fertilizers than from organic fertilizer. The higher nutrient losses from turf grown on subsoil were likely caused by the lower water infiltration capacity and reduced turfgrass quality. More sediment was lost from subsoil plots than from topsoil plots, which can be a factor in immobile P movement on soil particles. These findings underscore the importance of topsoil conservation in the urban landscape and also the potential benefits of organic over inorganic fertilizers in urban turfgrass lawn establishment and management.

The amount of nutrient loss is closely tied to the level of nutrient applied for both nitrogen and phosphorus. Sites receiving higher rates lost more nitrogen and phosphorus in runoff compared to sites receiving smaller applications. There is also a strong correlation between the timing of nitrogen and phosphorus and the potential for leaching, with the highest occurrence of nutrient runoff in the winter months when the turf and soil are frozen. In a study in Minnesota[6], peak phosphorus losses had a seasonal distribution that lagged P fertilizer application by three to six months. Greater phosphorus losses from a golf course in Minnesota[6] were measured during August, September, and October and corresponded to the onset of turfgrass dormancy time and when larger rainfall runoff events occurred. As a result, it was recommended that golf course and professional turfgrass managers explore the feasibility of altering phosphorus fertility management through the use of organic formulations, lower rate applications, and overall P rate reductions.

Fertilizer applications should also be avoided when soils are near saturation and heavy rainfall is forecasted. The first rain event after a fertilization application will produce the greatest nitrogen and phosphorus transport by runoff water[7].

4 Gan et al., Environ Sci Technol (2003) 37:2775-2779.
5 Cheng et al., Urban Ecosyt (2014) 17:277-289.
6 King et al., J Environ Monitor (2012) 14:2929-2938.
7 Nus and Kenna, Green Sect Rec (2012) 50(5).

A survey[8] of Baltimore County, Maryland, homeowners and lawn care professionals concluded that N from turfgrass fertilizers was a major component to the urban watershed nitrogen budget and there was a wide range in N application rates among homeowners and professionals, with application rates ranging from 0 to more than 4 lbs. N per 1,000 ft^2 annually. Research found that annual applications of greater than 5 lbs. nitrogen per 1,000 ft^2 on mature Kentucky bluegrass had the potential to produce unacceptable levels of nitrate leaching[9].

In a three-year study of Kentucky bluegrass grown on a silt loam soil with a 5% slope and high phosphorus level (27 ppm; Bray P1), P runoff was not increased by removing or recycling clippings back to the turf, but was increased in year 3 of the study by frozen conditions and increasing P treatments. It has also been reported that phosphorus runoff from lawns does not normally correlate to soil test P levels[10]. In fact, it has been concluded that phosphorus in turfgrass clippings is the predominant source of total P in runoff from urban landscapes, particularly when loss is predominantly from frozen soil[11]. Homeowners that apply high rates of phosphorus fertilizer and mulch clippings contribute to higher P runoff than homeowners that do not. Recent research also reports that in climates receiving snowfall and 3 or more months of soil freezing, between 80% and 87% of soluble phosphorus losses in home lawns occur from December through March[12]. In a 2013 study in Wisconsin, annual phosphorus runoff from an established Kentucky bluegrass turf was highly correlated to the amount of volume of the runoff with between 57% and 100% of runoff phosphorus collected when the soil was frozen.

Effect of Turfgrass Fertility on Pest & Disease Susceptibility

Soil nutrient levels and fertilizer applications are important factors in turfgrass pest and disease development. Excessive nitrogen applications can increase the susceptibility of cool-season grasses (Kentucky bluegrass, tall fescue, perennial ryegrass, fine fescue, and creeping bentgrass) to leaf spot, *Rhizoctonia* brown patch and *Pythium* blight), while inadequate nitrogen levels can increase turfgrass susceptibility to dollar spot and red thread. Inadequate soil potassium levels can reduce turfgrass tolerance to high temperatures and drought and increase the potential of some diseases including summer patch. Low pH is often associated with diseases such as brown patch. The return of clippings to Kentucky bluegrass, as compared to clipping removal, was associated with fewer weeds and a darker green more luxuriant turf. Slow-release nitrogen fertilizers were shown to reduce spring clipping yield and thereby make the practice of clipping return a more acceptable mowing practice[13].

Generally, a turf that is healthy and growing vigorously is best able to compete with weeds, insects, and diseases. Moreover, fertilizer-application timing or avoiding inadequate or excessive fertilization, can influence many pest problems. Fertilizing with water-soluble nitrogen during warm summer periods can increase the competitiveness of large or smooth crabgrasses as it grows in stands of cool-season turfgrasses. While applying fertilizers may not reduce sod webworm feeding, adequate irrigation and fertilization can help turf shoots outgrow sod webworm damage. Excessive nitrogen fertilization can be associated with brown patch, while inadequate nitrogen is often associated with dollar spot. Thus, maintaining fertility at levels that encourages dense turf growth without becoming excessive, along with mowing properly, are primary recommendations for encouraging turf health and competitiveness.

Beyond timing fertilizer applications to benefit turf and not crabgrasses, other common turf weeds can be influenced by fertilization practices. It has been reported that the fertilizing with phosphorus-containing fertilizers during periods of weed seed germination can encourage weed populations. In addition, to reduce the competitiveness of weedy warm-season annual grasses (e.g., barnyardgrass, fall panicum, and green and yellow foxtails), avoid applications of water-soluble nitrogen during hot portions of the summer growing season. To improve cool-season turfgrass competitiveness when invaded by the warm-season perennials yellow nutsedge, bermudagrass, nimblewill, and zoysiagrass, supply adequate

8 Law et al., J Environ Plan Mgt (2004) 47(5):737-755.
9 Nus and Kenna, Green Sect Rec (2012) 50(5).
10 Soldat and Petrovic, Crop Sci (2008) 48:2051-2065.
11 Steinke et al., J Environ Qual (2007) 36:426-439.
12 Steinke et al., J Environ Qual (2013) 42:1176-1184.
13 Heckman et al., J Sustain Agri (2000) 15(4):25-33.

nitrogen in the autumn while the desirable cool-season grasses are still growing and the warm-season invaders have gone, or are going, dormant.

Quackgrass, a cool-season perennial grass, is often found in settings that are under-fertilized with nitrogen or in soils of low fertility, while creeping bentgrass, another cool-season perennial grass, is usually more competitive in highly fertile or in heavily fertilized sites.

Supply adequate nitrogen in the fall when the warm-season annual broadleaf weeds knotweed and puncturevine, or biennial yellow rocket, a member of the Mustard family, are present. Black medic, a legume, grows as an annual, biennial, or perennial, and can compete with turf when nitrogen and/or phosphorus are inadequate or out of balance. Like black medic, white clover, another legume, is often an indicator of inadequate nitrogen fertility. Finally, dense turf that receives adequate nitrogen is better able to compete with dandelions, chicory, buckhorn plantain, sheep sorrel, and ground ivy.

Fertilizer application, along with irrigation, may help turf recover from the light or moderate feeding of various species of some insects including white grubs, sod webworms, and billbugs. Overall, however, reports of interactions between fertilization practices and insect pest presence in turf are scant. A Kentucky study reported that due to the possible attraction of adult white grub beetles to areas fertilized with natural, organic fertilizers (e.g., manures), grub populations may increase in those sites.

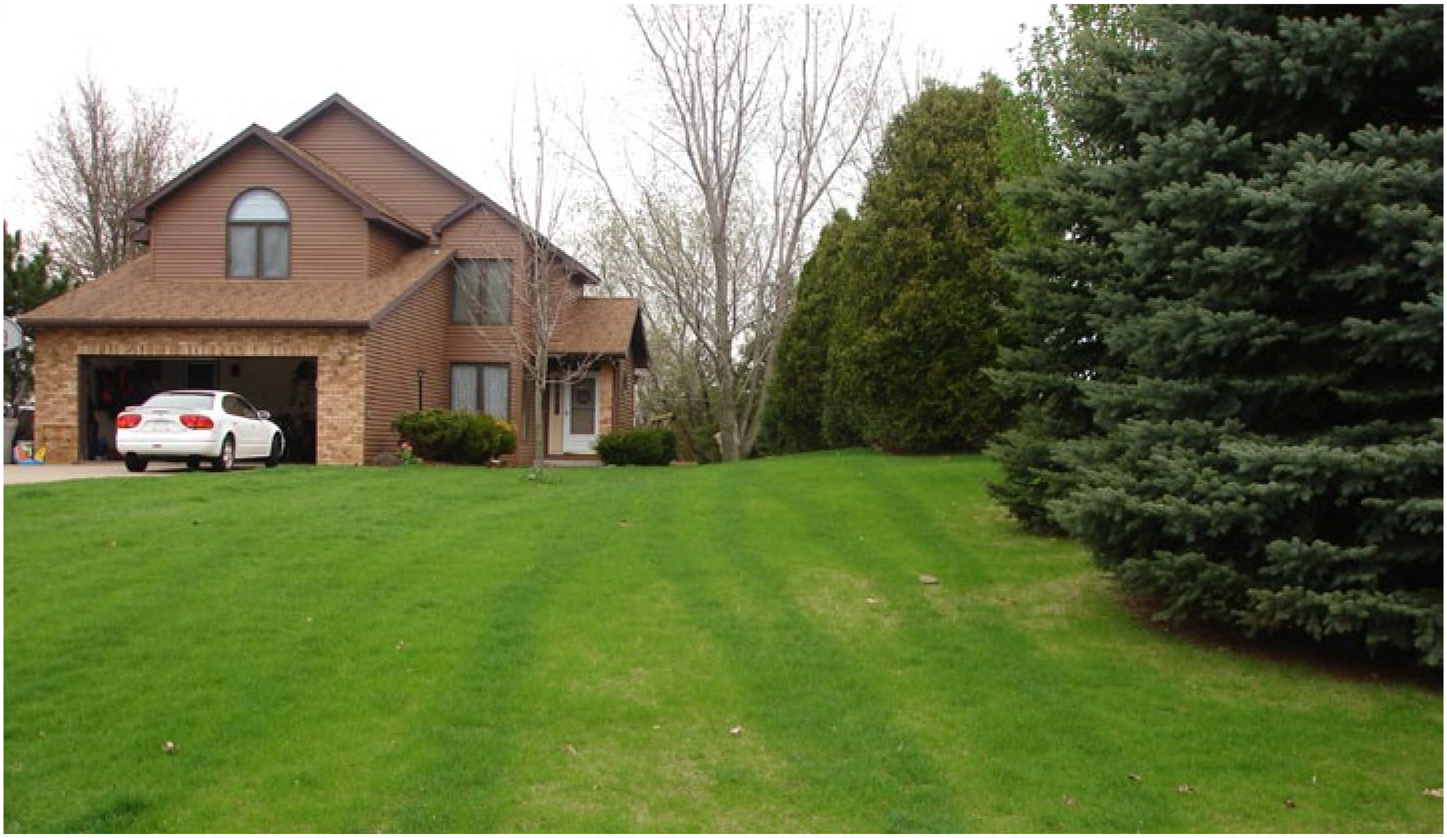
There has been much research conducted that examined the effects of mineral nutrients on disease presence in cool-season turfgrasses. Generally, the most damaging lawn diseases occur during summer months when high temperatures are often accompanied by drought. During hot summer months, avoid applications of quick-release sources of nitrogen that may encourage excessive cool-season turf growth. Applications of slowly released forms of nitrogen are recommended during these summer periods.

Applications of proper amounts of nitrogen will vary based on many factors. Inadequate fertilizer applications are commonly associated with several lawn diseases. Fertilizing can reduce diseases such as red thread, pink patch, rusts, dollar spot, anthracnose, summer patch, cerotic ring spot, some leaf spot organisms, frost scorch, and melting out. Conversely, applying too much fertilizer can increase *Pythium* blight, brown patch, gray leaf spot, leaf smuts, snow molds, powdery mildew, yellow patch, and downy mildew.

Nutrients other than nitrogen can also play a role in disease management, and using a balanced fertilizer, without excessive nitrogen, is recommended to maintain turf health. For example, inadequate levels of phosphorus, potassium, calcium, magnesium, manganese, and sulfur have all been connected to increased disease severity.

Proper Selection, Calibration, & Operation of Application Equipment

Turf fertilizer application equipment must be properly selected, calibrated, and operated in order to deliver fertilizer products at the correct rates, only to the turf. Fertilizers can be applied as a granular product with rotary, drop, or ride-on spreaders or as a liquid through sprayers or hose-ends. Regardless of the application equipment type or model, each individual piece of equipment differs other types. Therefore, calibration is critical, even though pieces of equipment may appear identical. Equipment should also be calibrated before application of a different fertilizer product due to variation in product density, size, active ingredients, and nutrient content. If calibration is done incorrectly, products may be misapplied and cause damage to turf, surrounding vegetation, and/or the environment. Information on proper application equipment calibration procedures can be found in regional Cooperative Extension or Land Grant University websites and publications (*see section on Turfgrass Nutrient Management Resources)*.



Proper fertilizer spreader calibration and application is critical to ensure uniform turfgrass response.

Illinois Laws & Regulations Affecting Turfgrass Nutrient Applications

As of 2012, eleven states (IL, MI, MN, WI, ME, MD, NJ, NY, VT, VA, and WA) have passed legislation regulating the application of P to existing stands of turfgrass. Most of these restrictions have focused on professional turfgrass applications, but several states also include homeowner regulations (Table 12). In general, these states prohibit phosphorus fertilizer application unless it corrects an identified P deficiency or is used in turfgrass establishment or repair. Many states exempt golf courses, sod farms, and agricultural production from regulation. Many also prohibit applying phosphorus and other fertilizers on impervious, frozen or saturated surfaces, and within specified proximities to surface waters. Phosphorus bans in individual municipalities or county-based restrictions on P applications can exist where there is no statewide prohibition. For example, while there is not a state-wide P ban, a number of Florida cities and counties in the state have passed fertilizer ordinances that do not allow applications of nitrogen or phosphorus fertilizers during the summer due to leaching caused by heavy seasonal rainfall.

IL laws & regulations affecting nutrient applications to residential and commercial turfgrass

In 2008, Antioch, Third Lake, and Lindenhurst municipalities in Lake County, IL and Crystal Lake and Lakewood municipalities in McHenry County, IL adopted phosphorus application bans. Proposals were brought before the Illinois legislature to restrict P applications statewide to residential and urban areas. In February 2009, House Bill #3817 *Phosphorus Turf Fertilizer Use Restriction Act* was introduced and was defeated in the legislature.

Illinois House Bill #6099 was passed in 2010. This Bill amended Sections 2 and 7 and added Sections 5a and 9 to the Illinois Compiled Statue 415 ILCS 65, *The Lawn Care Products Application and Notice Act*, and limited the application of P fertilizers by "for hire" turfgrass professionals. According to the *Act*, "A 'for hire' applicator means any person who makes an application of lawn care products to a lawn or lawns for compensation, including applications made by an employee to lawns owned, occupied or managed by his employer and includes those licensed by the Department [of Agriculture] as licensed commercial applicators, commercial non-for-hire applicators, commercial public applicators, certified applicator and licensed operators and those otherwise subject to the licensure provisions of the Illinois Pesticide Act".

The law prevents "for hire" applicators from:

1) applying phosphorus-containing fertilizers to established turfgrass unless a soil test establishes a need;
2) applying fertilizer to impervious surfaces (meaning "any structure, surface, or improvement that reduces or prevents absorption of storm water, in land, and included pavement, porous paving, paver blocks, gravel, crushed stone, decks, patios, elevated structures, and other similar structures, surfaces, and improvements");
3) applying fertilizer using a spray, drop, or rotary spreader with a deflector within a 3-foot buffer of any water body;
4) applying fertilizers without such application equipment within 15 feet of any water body; and
5) applying fertilizer any time when a lawn is frozen (typically 3 or 4 inches deep) or saturated (inundated by standing water).

Professionals exempt from these restrictions are operators of commercial farms, lands classified as agricultural lands, and golf courses.

TABLE 12

Summary of Midwestern Laws Regulating the Application of Phosphorus Fertilizers to Turfgrass

Stipulation	Illinois	Wisconsin	Michigan	Minnesota
Year P restriction was enacted	2010	2010	2012	2004
Applicators affected	"Applicator for hire" (Licensed commercial, certified applicators, and others)	All persons (Professionals & homeowners)	All persons (Professionals & homeowners)	All persons (Professionals & homeowners)
When P fertilizers can be applied	Deficiency, established new turf, lawn repair	Deficiency, established new turf	Deficiency, established new turf	Deficiency, established new turf
Exempt applications	Golf courses, commercial and sod farms, agricultural lands and production, rights-of-way	Sod farms, agricultural lands and production	Golf courses, commercial farm land	Golf courses, sod farms, agricultural lands and production
Application to paved or impervious surfaces	Prohibited, must be cleaned up if inadvertent	Prohibited, must be cleaned up if inadvertent	Must be cleaned up if applied	Prohibited, must be cleaned up if inadvertent
Setback from surface water (buffer)	3 to 15 ft setback	None	3 to 15 ft setback	None
Application of P on frozen or saturated soils	Prohibited	Prohibited on frozen ground	Prohibited	No restrictions
Restrictions on P lawn fertilizer sales	No restrictions	No display, must sell only for specific purposes	No restrictions	No restrictions
Enforcement	Dept. of Agriculture, Attorney General	Local governmental units	Dept. of Agriculture, Attorney General	Dept. of Agriculture
Penalty for non-compliance	$250-$1,000	$50-$1,000	$50-$1,000	Varies by local unit
State needs to provide consumer information on P	No requirement	No requirement	Required	Required

Adapted from Miller, *Connecticut General Assembly Research Report* (2012); 2012-R-0076.

According to the law, the soil test that establishes that the soil is P-deficient, or lacking in P, must be compared against the standard established by the University of Illinois, which has been established using the Bray P1 soil extraction method. If the soil tests greater than 15 ppm P (or greater than 30 lbs. P_2O_5 per acre; which translates to 0.70 lbs. P_2O_5 per 1,000 ft^2), phosphorus application is restricted. If the soil tests below these levels, the situation is considered P deficient, and phosphorus may legally be applied by a "for hire" professional following the recommendations in Table 13.

TABLE 13

Phosphorus deficiency levels for established Illinois turfgrass

Phosphorus Level; Bray P1 Extraction Method[a]	Phosphorus Level; Bray P1 Extraction Method[a]	Recommended P Application Level
lbs. of P_2O_5 per Acre	ppm P	lbs. of P_2O_5 per 1,000 ft^2
0-15	0-7.5	1
15-30	7.5-15	0.5
>30	>15	0

[a] Many soil testing laboratories are utilizing the Mehlich-3 test in place of the Bray P1 test. Both tests use similar extraction techniques, but Mehlich-3 tends to extract more P than does the Bray P1 test.

Adapted from Branham, *Illinois Pesticide Review Newsletter* (2011) January/February.

Frequently Asked Questions

"Why should lawns be fertilized?"

Obviously, there are no laws requiring turf fertilization. However, unfertilized, or even under-fertilized turf is usually of low quality and commonly off-colored, thin, open, and weedy. Unfertilized turf recovers slowly when damaged by pests or traffic. Moreover, a low-quality lawn can reduce the "curb appeal" of a residence, neighborhood, or business and reduce property values.

"How can I quickly green up a client's lawn?"

Applications of chelated iron is the most rapid way to green up a lawn. Quick release ammonium-N fertilizers also green up turf rapidly.

"Why are phosphorus fertilizers regulated on IL turfgrass?"

Phosphorus is often the most limiting nutrient in an aquatic environment. When P moves from lawns into surface water, either by runoff due to excessive irrigation, rainfall or snowmelt, or by soil particle movement due to erosion, it can create harmful algae blooms (eutrophication), degrade habitats for fish and other aquatic wildlife, and reduce water oxygen levels. Due to these harmful environmental effects, legislatures in Illinois and many other states have regulated P application to turfgrass.

"Can I apply phosphorus to lawns in an organic form and still be in compliance to the IL phosphorus law?"

Although there are several exemptions listed in the IL Phosphorus Application Law, the terms "natural" and "organic" on phosphorus fertilizers are not enough to allow application unless a soil test shows a deficiency according to University of Illinois criteria or if it is an establishment or repair situation. The application of animal or vegetable manure is allowed under the regulation, even if the manure contains a small amount of phosphorus. However, the exemption will only be valid if the product has no phosphorus added to it and the label clearly states it is "manure".

"When should I be concerned about phosphorus if I have started using zero-P fertilizers?"

We have not seen a confirmed phosphorus deficiency in an established Illinois lawn. There is potential for phosphorus deficiency to show up on newly seeded lawns or lawns growing in sandy soils, but the condition is rare in residential soils. Phosphorus (and iron) availability are linked to soil pH and when pH is high (alkaline), these nutrients become unavailable for uptake. This is why a soil pH of 6.0 to 7.0 is desirable for nutrient availability in turfgrass settings. If you suspect a phosphorus deficiency, perform a soil test and a plant tissue test for confirmation.

"Why do weeds keep returning each year after I apply a herbicide to control them?"

In situations like this, herbicide treatments are only treating a "symptom" (the presence of weeds) and are not correcting the "cause" of the problem (why the weeds are present). Although herbicides can provide effective weed control, they are not substitutes for proper turfgrass management such as fertilization and mowing. Under-fertilized turfgrass competes poorly with weeds, while improper fertilizer application timing (e.g., a mid-summer application of quick-release N) will encourage warm-season annual weeds such as crabgrass to be more competitive than cool-season turfgrass. Developing a healthy, dense stand of turfgrass is a primary weed control strategy.

"Why are some lawns in Central and Southern IL only green in summer and not in the fall and spring?"

There are Illinois lawns planted with warm-season turfgrass species such as zoysiagrass and bermudagrass. These grasses are well adapted to high temperatures and grow actively from May to October in IL. In comparison, cool-season grasses (e.g., Kentucky bluegrass, perennial ryegrass, tall fescue, and fine fescue) grow actively at cooler temperatures in the spring and fall, with best turf quality typically occurring in April to May and September to October. It is important to identify the grass species because fertilizers will not green up a dormant turfgrass.

"What is "organic" lawn care and what level of turf quality can I expect if I maintain a client's lawn using only organic products?"

True organic lawn care typically relies on applications of naturally occurring fertilizers and pest controls, and avoids using synthetic products. From a nutrient uptake perspective, plants absorb nutrients as ionic forms of mineral elements. For example, there is no difference in the ammonium-N (NH_4^-) that roots absorb whether it originates from a synthetic or organic source. This is the same for other minerals as well; sulfur is taken up by turf plants in the SO_4^{2-} and iron in the Fe^{2+} or Fe^{3+} forms regardless of the source. There are differences, however, between man-made and naturally-occurring fertilizers, such as the soil benefits derived from applications of organic products, the speed of nutrient availability, the completeness of the suite of nutrients in the product, the quantity of product needed to achieve the desired quality, and the cost of the source.

"What about the use of biosolids and compost teas?"

Biosolids are organic products that result from urban sewage treatment. Some have been successfully used as soil amendments during turf establishment or as turf fertilizers. As turf fertilizers, biosolids are a complete fertilizer, generally with low amounts of N. Select Class A biosolids as turf fertilizers; Class A biosolids have been approved for land applications by the U.S. EPA and meet the Agency's pathogen level and metal concentration guidelines. Also, be aware that salt and P levels in biosolids can be high, there is sometimes an unpleasant odor, and viable weed seeds can be present in some products.

Compost teas are liquids that have been extracted from compost, sometimes with the additions of commercial supplements or starters. Under the best circumstances, compost teas are rich in beneficial microorganisms and plant-growth compounds. Obviously, the quality of compost teas can be variable due to the variety of source materials and the methods used to produce and extract the liquid. It should be noted that compost teas have been used successfully to enhance plant health and quality in some professional horticultural settings, but these liquids should not be relied upon as fertilizers or pest control products.

Lawn care professionals should educate homeowners about organic fertility programs and compost teas so that these clients are aware of the potential advantages and limitations.

"How late in the season can fertilizer be applied?"

Current research on the environmental effects of late fall fertilization to turfgrass has been conducted on the east and west coasts. However, research specific to Illinois climate and soils is still needed. What is certain is that fertilization application should ***never*** be made to frozen soils. Annual lawn fertilization in IL should be completed by late October or early November to ensure nutrients are best used by turfgrasses.

"How should I apply fertilizers next to surface waters such as ponds?"

Applying fertilizers or pest-control products in a way that allows the materials to runoff into surface water is undesirable. To intercept runoff before it reaches the water's edge, it is recommended that an untreated buffer strip be maintained at the water's edge. The IL Phosphorus Application law states that applying fertilizer using a spray, drop, or rotary spreader with a deflector within a 3-foot buffer of any water body or applying fertilizers without such application equipment within 15 feet of any water body is strictly prohibited. To enhance fertilizer and pesticide interception, mow the untreated strip closest to the lawn at lawn height and add additional strips of increasing heights so that the buffer strip vegetation closest to the water is unmowed or at least much taller than lawn height.

"Even after they're fertilized, some lawns aren't very green. Why?"

Many homeowners desire a dark green lawn and are unaware that not all turfgrasses, even when receiving appropriate fertilization, will be dark green. Turf species can vary greatly in genetic color. For example, there have been more that 100 commercial cultivars of Kentucky bluegrass available to homeowners over the past 20 years. While a primary goal of many turf breeders and seed producers is to produce dark-green types, there is still a great deal of color variability with some types being far darker than others. To maintain a dark-green turf, plant a genetically dark-green grass. Visit the National Turfgrass Evaluation Program (NTEP) website (www.ntep.org) for lists of turf cultivars that are dark green and perform well in various U.S. locations.

"Should my clients irrigate their lawns?"

Without irrigation, most cool-season turf lawns will go dormant during prolonged dry spells. Following most Illinois summer dry spells, dormant turf will recover with autumn rains and cooler temperatures. On the other hand, irrigating cool-season lawns can maintain turf color and active growth during dry periods and can also assist the turf's ability to compete with weeds. If lawns are to be irrigated, it is recommend that 1 to 1.5 inches of water be supplied per week in 1 or 2 applications. With this application rate, the turf should maintain green color and moderate growth. Obviously, community bans during severe droughts will need to be heeded and fertilizing in the fall following a drought can encourage turf recovery.

"My new client claims they do a better job of caring for their lawn than their neighbor, but the neighbor's lawn looks better. Why?"

There are several possible explanations for this. While the growing conditions and management activities of near-by properties may appear to be similar, differences in soils, microclimates around residences, and types of lawn grasses (species or varieties) may alter turf performance. In addition, slight management differences, such as fertilizer application timing, rates, and products can also alter turf performance. For example, the height difference when mowing adjacent Kentucky bluegrass lawns at 2 inches and 2.5 inches may not be visually apparent, but the taller lawn has potentially 25% more leaf tissue for carbohydrate production than the shorter lawn and can also develop a deeper root system. A deeper root system and increased photosynthesis can enhance turf growth and appearance.

"Will it hurt my newly seeded (or sodded) lawn if it's fertilized?"

It's important that new lawns, whether started from seed or sod, receive adequate fertilizer. When preparing sites for seeding or sodding, incorporate starter fertilizer at the rate recommended on the fertilizer package or 10 pounds of 10-10-10 fertilizer per 1,000 ft2, into the root zone. After planting, newly seeded lawns should be fertilized with approximately 1/2 pound of N per 1,000 ft^2 when the turf reaches 1/2 inch to maintain growth and encourage density. Moreover, it's important that newly seeded lawns be mowed as turf reaches the desired height to also encourage growth in open areas and improve turf density through tillering. After establishment, seeded lawns should be fertilized based on the desired schedule. To speed development, sod producers often fertilize heavily to encourage turf growth. Heavy fertilization is not necessary on the newly sodded sites; as with seeded lawns, after establishment, fertilize based on the desired schedule.

"Shouldn't shaded turf be fertilized heavily to make up for the lack of light?"

University researchers have reported that lawns growing in shade should receive about 1/2 the fertilizer application rate of turf growing in full sun due to a reduced light available for photosynthesis. Additionally, turf growing in shade requires at least 30% of full sunlight to maintain reasonable quality. Also, maintain balanced turf nutrition (especially adequate P and K), restrict traffic, and prune trees and shrubs to improve light availability and air movement in shaded areas.

Turfgrass Nutrient Management Resources

The following books and resources can be obtained from your local school library, bookstore, cooperation extension office, or purchased on-line through a simple Google search.

General Turfgrass References:

- Beard, J.B. 1972. Turfgrass: Science and Culture. Prentice-Hall.
- Beard, J.B. 1979. How to Have a Beautiful Lawn. Intertec Publishing Corp.
- Christians, N., 2011. Fundamentals of Turfgrass Management. 4th ed. John Wiley & Sons.
- Danneberger, T.K., 1993. Turfgrass Ecology and Management. G.I.E. Media Inc.
- Emmons, R. & F.S. Rossi. 2015. Turfgrass Science and Management. 5th ed. Delmar Learning/Cengage
- Fry, J. & B. Huang. 2004. Applied Turfgrass Science and Physiology. John Wiley & Sons.
- Musser, H.B. 1962. Turf Management. McGraw-Hill Book Company, Inc.
- Turgeon, A.J., 2012. Turfgrass Management. 9th ed. Prentice-Hall.

Specialized Turfgrass References:

- Agnew, M. N. Agnew, A. M. VanDerZanden, and N. Christians. 2008. Mathematics for the Green Industry: Essential Calculations for Horticulture and Landscaping Professionals. Wiley.
- Beard, J.B. 2001. Turf Management for Golf Courses, 2nd Edition. Wiley.
- Beard, J.B. 2005. Beard's Turfgrass Encyclopedia for Golf Courses, Grounds, Lawns, Sports Fields. Michigan State University Press.
- Brede, D. 2000. Turfgrass Maintenance Reduction Handbook: Sports, Lawns, and Golf. John Wiley & Sons.
- Casler, M.D. and R.R. Duncan (eds.). 2003. Turfgrass Biology, Genetics, and Breeding. 2003. John Wiley & Sons, Inc., Hoboken, New Jersey.
- Christians, N. and M. Agnew. The Mathematics of Turfgrass Maintenance. 2008, 4th Edition. Wiley.
- Dunn, J. and K. Diesburg. 2004. Turf Management in the Transition Zone. John Wiley & Sons, Inc., Hoboken, New Jersey.
- Fagerness, M. and R. Johns. 2003. Turfgrass Chemicals and Pesticides: A Practitioner's Guide. McGraw-Hill Professional.
- Pedersen, D. and T. Voigt. 2005. Identifying Turf and Weedy Grasses of the Northern United States. C1393. University of Illinois Extension. (https://pubsplus.illinois.edu/C1393.html pubsplus.uiuc.edu).
- Turgeon, A.J. and J.M. Vargas. 2005. The Turf Problem Solver: Case Studies and Solutions for Environmental, Cultural and Pest Problems. Wiley.
- Vengris, J. & W.A. Torello. 1982. *Lawns*. Fresno: Thomson Publications.

Fertilizer Application (Calibration):

- U. of MN. Calibrating Your Spreader to Ensure Accurate, Cost-Effective Fertilizer Application. (http://www.extension.umn.edu/garden/landscaping/maint/selectin_10.html).
- NC State U. The Calibration of Turfgrass Boom Sprayers and Spreaders. (https://www.bae.ncsu.edu/extension/ext-publications/water/irrigation/ag-628-Calibration_of_Turfgrass_Boom_Sprayers_and_Spreaders.pdf).
- Penn. State U. Calibrating Your Fertilizer Spreader. (http://plantscience.psu.edu/research/centers/turf/extension/factsheets/calibrating-spreader).
- Purdue U. Calibrating Ride-on Pesticide Sprayers and Fertilizer Spreaders. (https://ag.purdue.edu/extension/ppp/Documents/PPP-104.pdf).
- Purdue U. Calibrating the Hose Reel Lawn Care Sprayer. (https://www.extension.purdue.edu/extmedia/PPP/PPP-85.pdf).
- Purdue U. Lawncare Pesticide Application Equipment. (https://www.extension.purdue.edu/extmedia/ppp/ppp-46.pdf).

Fertilizers, Soils, and Nutrition References:

- Carrow, R.N., D.V. Waddington, and P.E. Rieke. 2002. Turfgrass Soil Fertility and Chemical Problems: Assessment and Management. John Wiley & Sons.
- Carrow, R.N. and R.R. Duncan. 1998. Salt-Affected Turfgrass Sites: Assessment and Management. John Wiley & Sons.

General Pest Identification and Management References:

- Baxendale, F.P. & Gaussoin, R.E. (eds.). 1997. Integrated Turfgrass Management for the Northern Great Plains. Univ. of NE Publication EC97-1557.
- Converse, J. Scotts Guide to the Identification of Turfgrass Diseases and Insects. 1987. The O.M. Scott & Sons Co., Marysville, Ohio.
- Fermanian, T.W., M.C. Shurtleff, R. Randell, H.T. Wilkinson, & P.L. Nixon. 2002. Controlling Turfgrass Pests. 3rd ed. Prentice-Hall.
- Gussack, E. & F.S. Rossi. 2001. Turfgrass Problems: Picture Clues and Management Options (NRAES-125). Ithaca: Natural Resource, Agriculture, and Engineering Service.
- Leslie, A.R. 1994. Handbook of Integrated Pest Management for Turf and Ornamentals. CRC Press.
- McCarty, L.B., I.R. Rodriguez, B.T. Bunnell, F.C. Waltz. 2003. Fundamentals of Turfgrass and Agricultural Chemistry. John Wiley & Sons, Inc.
- Turgeon, A.J. and J.M. Vargas. 2005. The Turf Problem Solver: Case Studies and Solutions for Environmental, Cultural and Pest Problems. John Wiley & Sons.
- Watschke, T.L., P.H. Dernoeden, and D.J. Shetlar. 2013. Managing Turfgrass Pests – 2nd ed. CRC Press.

Diseases Identification and Management References:

- Burpee. L. 1993. A Guide to Integrated Control of Turfgrass Diseases, Vol. 1: Cool Season Turfgrasses. GCSAA Press.
- Couch, H.B. 1995. Diseases of Turfgrasses. 3rd ed. Krieger Publishing Co.
- Couch, H.B. 2000. The Turfgrass Disease Handbook. Krieger Publishing Co.
- Latin, R. 2011. A Practical Guide to Turfgrass Fungicides. APS Press.
- Smiley, R.W., P.H. Dernoeden, & B.B. Clarke. 2005. Compendium of Turfgrass Diseases. 3rd ed. APS Press.
- Tani, T. & J.B. Beard. 2002. Color Atlas of Turfgrass Diseases. John Wiley & Sons.
- Vargas, J. 2004. Management of Turfgrass Diseases. 3rd ed. John Wiley & Sons.

Insect Identification and Management References:

- Brandenburg, R.L. and C.P. Freeman. 2012. Handbook of Turfgrass Insect Pests. APS Press.
- Niemczyk, H.D. 2001. Destructive Turf Insects. 2nd ed. G.I.E. Media Inc., Cleveland, OH.
- Potter, D.A. 1998. Destructive Turfgrass Insects: Biology, Diagnosis, and Control. John Wiley & Sons.
- Shetlar, D.P. Heller, and P. Irish. 1990. Turfgrass Insect and Mite Manual. 3rd ed. Pennsylvania Turfgrass Council, Boalsburg, PA.
- Vittum, P., M.G. Villani, and H. Tashiro. 1999. Turfgrass Insects of the United States and Canada – Second Edition. Cornell University Press.

Weed Identification and Management References:

- McCarty, L.B., J.W. Everest, D.W. Hall, T.R. Murphy, & F. Yelverton. 2008. Color Atlas of Turfgrass Weeds – Second Edition. John Wiley & Sons.
- Converse, J. 1985. Scotts Guide to the Identification of Grasses. The O.M. Scott & Sons Co., Marysville, OH.
- Converse, J. 1985. Scotts Guide to the Identification of Dicot Turf Weeds. The O.M. Scott & Sons Co., Marysville, OH.
- Turgeon, A.J. 1994. Turf Weeds and Their Control. American Society of Agronomy.
- Applied Weed Science-2nd Edition. 1999. Ross, Merrill A. and Lembi, Carole A. Prentice-Hall, Inc. Upper Saddle River, NJ. 452 pages. ISBN 0-13-754003-5.
- Royer, F. & R. Dickinson. 1999. Weeds of the Northern U.S. and Canada: A Guide for Identification. The University of Alberta Press.
- USDA ARS. 1971. Common Weeds of the United States. New York: Dover.
- Uva, R.H., J.C. Neal, & J.M. Ditomaso. 1997. Weeds of the Northeast. Cornell University Press/Comstock Publishing.

Useful University Websites:

Please conduct an on-line Google search for the following resources using the name of the university and the title of the publication if the hyperlink does not work.

- U. of California. Practical Lawn Fertilization (Publication 8065). (http://anrcatalog.ucdavis.edu/pdf/8065.pdf).
- U. of Georgia. Best Management Practices for Turfgrass Water Conservation. (https://commodities.caes.uga.edu/turfgrass/georgiaturf/Publicat/1650_BMP_H2O.htm).
- Purdue U. Turfgrass Identification Tool. (https://www.agry.purdue.edu/Turf/tool/index.html).
- Purdue U. Fertilizing Established Cool-season Lawns: Maximizing Turf Health with Environmentally Responsible Programs. (https://www.extension.purdue.edu/extmedia/AY/AY-22-W.pdf).
- Michigan State U. Fertilizing Home Lawns to Protect Water Quality (E0001TURF). (http://msue.anr.msu.edu/resources/fertilizing-home-lawns-to-protect-water-quality).
- U. of Minnesota. Preventing pollution problems from lawn and garden fertilizers. (http://www.extension.umn.edu/garden/turfgrass/fertilizers/preventing-pollution-problems/index.html).
- U. of Minnesota. Fertilizing Lawns. (ww.extension.umn.edu/garden/turfgrass/fertilizers/fertilizing-lawns/index.html).
- U. of Minnesota. Understanding and Using Lawn Fertilizers. (http://www.extension.umn.edu/garden/landscaping/maint/selectin.htm).
- U. of Nebraska. What's the ideal fertilizer ratio for turfgrass? (http://turf.unl.edu/turfinfo/Ideal%20Fertilizer%20Ratio.pdf).
- The Ohio State University. Turfgrass Identification. (http://buckeyeturf.osu.edu/pdf/01_turfgrass_identification.pdf).
- Penn. State U. Turfgrass Fertilization: A Basic Guide for Professional Turfgrass Managers. (http://plantscience.psu.edu/research/centers/turf/extension/factsheets/turfgrass-fertilization-professional).
- U. of Wisconsin. Lawn Fertilization (A2303). (http://learningstore.uwex.edu/assets/pdfs/A2303.pdf).
- U. of Wisconsin. Turf Diseases of the Great Lakes Region (A3187). (http://learningstore.uwex.edu/Assets/pdfs/A3187.pdf).
- U. of Wisconsin. Organic and reduced-risk lawn care. (http://learningstore.uwex.edu/Assets/pdfs/A3958.pdf).
- U. of Wisconsin. Organic Lawn Fertilization. (http://hort.uwex.edu/files/2014/11/Organic-Lawn-Fertilization.pdf).
- U. of Wisconsin. Identifying grasses in Wisconsin turf (A1827). (http://learningstore.uwex.edu/Assets/pdfs/A1827.pdf).

While not directed toward the lawn professional, these golf-turf resources can provide valuable information and can be obtained from your school library, local bookstore or through the GCSAA Store online at www.cswebstore.net/gcsaa/

- GCSAA's monthly publication Golf Course Management magazine.
- Milligan, R.A. and T.R. Maloney. 1996. Human Resource Management for Golf Course Superintendents. Wiley.
- Schmidgal, R.S. 2003. Superintendent's Handbook of Financial Management. Wiley.
- GCSAA Glossary of Turfgrass Terminology. (https://www.gcsaa.org/UploadedFiles/Course/Communication/Information-for-Golfers/Word-file--Turfgrass-terminology.doc).

The Illinois Nutrient Research & Education Council (NREC) was created by state statute in 2012. Funded by a 75-cent per ton assessment on bulk fertilizer sold in Illinois, NREC provides financial support for nutrient research and education programs to ensure the discovery and adoption of practices that address environmental concerns, optimize nutrient use efficiency, and ensure soil fertility.

A 13-member NREC Council annually solicits, reviews and funds projects that fulfill the organization's mission. More information can be found at www.illinoisnrec.org.

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