ATHLETIC FIELD FERTILIZATION

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A good playing surface on athletic fields is critical to insure best athlete performance and athlete safety. A key agronomic practice needed to maintain a safe, aesthetically pleasing and suitable playing surface is fertilization. In fact, proper fertilization will do more to improve athletic field conditions than perhaps any other agronomic practice.

Turfgrass growth on athletic fields is dependent upon an adequate supply of all essential plant nutrients, as well as a multiplicity of other cultural and edaphic factors. Research in plant nutrition has shown at least 16 elements are essential for plant growth and development (Table 1). Those essential elements used in greatest quantities by plants are referred to as macronutrients. Micronutrients are required in relatively small quantities by the plant. Nitrogen receives the most attention in turfgrass fertilization programs for several reasons. First, nitrogen is the essential element to which turfgrass is most responsive. Nitrogen can be described as the "growth-control element". Supplies of other elements are kept at adequate levels and the manager regulates growth by adding or withholding nitrogen. Second, the turfgrass plant contains more nitrogen than any other essential element. Third, nitrogen is a very dynamic element in the soil system. Its concentration in the soil is constantly changing. It may be depleted or lost from soils by leaching, volatilization, denitrification, immobilization, clipping removal, or nitrogen fixation in the lattice structure of certain clays. The other essential elements are more stable in soils. Thus, nitrogen must be added to turfgrass areas on a routine basis to maintain a soil level that is sufficient for turfgrass growth.

Generally, nitrogen additions to the turfgrass system from clipping return, decomposition of organic matter, topdressing, nitrogen fixation, and rainfall are not sufficient to supply the needs of a high-quality turf. The main source of added nitrogen is nitrogeneous fertilizers, which are initially added to the turfgrass system as ammonium (NH+), nitrate (NO-), or both or as some nitrogen carrier that eventually breaks down to ammonium. Although the turfgrass absorbs nitrogen from the soil as either ammonium or nitrate, the latter is the predominant form absorbed by the plant because ammonium is rapidly converted to nitrate by soil bacteria. This biological oxidation of ammonium to nitrate is nitrification, a two-step process in which ammonium is converted to nitrite (NO-) by Nitrosomonas bacteria and then to nitrate by Nitrobacter bacteria. The process is temperature dependent and increases with soil temperatures from 32 F to an optimum range of 85 to 95 F.

Once absorbed into the plant, nitrate can be stored in the cell or reduced back into the ammonium form. The storage of free nitrate within the plant cells results in a luxury consumption of nitrate (absorption of more than used). This use of nitrogen is probably inefficient, especially if the clippings are removed. Nitrogen must be converted to the ammonium form before it can be further utilized by the plant. The reduction process (NO- to NH+) within the plant requires at least two enzymes (compounds that assist in the reduction). Nitrate reductase is the enzyme involved in the conversion of nitrate to nitrite. Nitrite reductase is the enzyme involved in the conversion of nitrite to ammonium. In grasses, the reduction process predominantly occurs in the shoot or foliar portion of the plant, although some reduction may occur in the roots. The ammonium ion is then readily combined into various complex organic (carbon) compounds within the plant. Chlorophyll, amino acids, proteins, enzymes, and vitamins are among some of the organic compounds containing nitrogen. Photosynthesis provides the source of carbohydrates or organic skeletons for the nitrogen assimilation processes. Photosynthesis is a carbohydrate-producing process.

Carbohydrates, produced by photosynthesis, are the necessary precursors for the formation of nitrogen-containing amino acids and proteins, which are utilized in the growth process. The more the turfgrass grows, the greater its demand for carbohydrate. Growth is a carbohydrate-utilizing process. Carbohydrate is also the key source of energy for maintaining all the various growth and physiological processes within the plant. Carbohydrates are broken down into carbon dioxide and water through respiration, and energy is released. Respiration therefore is a carbohydrate-utilizing process. When the rate of photosynthesis (carbohydrate production) exceeds the rate of respiration and the requirement for growth (carbohydrate utilization), carbohydrates accumulate as reserves. These reserves are usually stored in the crowns, rhizomes, and stolons of cool-season grasses. Carbohydrate reserves are desirable because they serve as an immediate source of energy and carbon skeletons for regrowth and recovery from defoliation or stresses that may injure or thin the turf. Recovery and regrowth from summer and winter dormancy relay on carbohydrate reserves. A carbohydrate deficit may develop when respiration rates are high, growth is rapid, or both. Usually any factor that stimulates rapid topgrowth will deplete or drain carbohydrate reserves. The turfgrass manager should manipulate cultural practices so as to maintain an adequate level of carbohydrates within the plant for normal as well as unusual energy and growth demands. The carbohydrate reserve status of the plant is important because it reflects the plant`s energy, recovery, and stress tolerance status.

Nitrogen fertilization has a definite effect upon the carbohydrate status of turfgrasses. Nitrogen applications favor turfgrass growth. As nitrogen rates are increased, usually more topgrowth is produced. More topgrowth results in the use of more carbohydrate. Like shoots, roots and rhizomes require carbohydrate (carbon skeletons) for growth. Physiologically, under rapid growth conditions shoots take priority over roots and rhizomes for available carbohydrate. Shoot growth will usually continue to respond to higher nitrogen levels under favorable climate conditions causing a distinct suppression of root growth and other growth processes (e.g., rhizomes).

These effects are will illustrated by a fertilization study evaluating the response of a Merion Kentucky bluegrass sod to incremental rates of nitrogen (Table 2) (Rieke, 1975). Higher nitrogen rates resulted in an increase in clipping yield (topgrowth) and the nitrogen content of the clippings. In contrast, sod strength (a reflection of root and rhizome growth) and rhizome weight decreased at the higher nitrogen levels.

Table 1. Essential plant nutrients required for turfgrass growth and development.[a]

Macronutrients	Typical Percentage in Turfgrass Tissue[b]
Nitrogen	3-6
Phosphorus	.2-.5
Potassium	2-3
Calcium	.4-.6
Magnesium	.2-.4
Sulfur	.2-.3
Micronutrients	**Typical Parts Per Million (ppm) in Turfgrass Tissue**
Iron	40-200
Zinc	40-120
Molybdenum	.1-.2
Manganese	20-150
Copper	15-20
Boron	5-20

[a] Carbon, hydrogen and oxygen are also essential elements supplied predominantly from air and water.
[b] Elemental percentages will vary to some extent depending on turfgrass species and cultivars, environmental conditions and other variables.

Table 2. Nitrogen treatment effects on a Merion Kentucky bluegrass sod.[a]

Nitrogen rate	Annual clipping yield	Nitrogen content in clippings	Sod Strength	Rhizomes
lb/acre/month	lb/acre dry wt	%	lbs to tear	grams
0	463	3.0	146	99
15	1,807	3.3	188	89
30	2,555	3.6	130	120
60	5,676	4.5	97	43
120	8,447	5.4	67	14

[a] Rieke, 1975.

Thus, when most of the plant's carbohydrate was directed toward producing shoot growth, root growth and other plant growth processes suffered accordingly. Agronomists recognize that a grass plant is no better than the root system that supports it. Roots and rhizomes in addition to producing a more physiologically sound turfgrass plant provide for a stronger sod with enhanced playability characteristics.

A considerable amount of root initiation and root growth of cool-season grasses occurs in the spring and fall when soil temperatures are cool (Beard and Daniels, 1966, Koski, 1983). Liberal nitrogen fertilization in the spring will increase top-growth at the expense of root growth. In turn, a considerable amount of good "root growth growing weather" will be lost in the spring where high spring fertilization is used. The turfgrass plant will go into the summer with a shorter root system than if low to moderate rates of nitrogen were used.

Furthermore, high amounts of spring nitrogen will increase topgrowth and the need for more frequent mowing in the spring. Rapid topgrowth may result in the removal of large amounts of clippings at each mowing. This is undesirable agronomically since removal of excess topgrowth or foliage is known to retard both tiller and root development. The degree of defoliation will influence the time delay in tiller and root development. It is recommended that no more than a third of the foliage be removed at any one mowing. A high nitrogen rate in spring not only has a direct negative effect by favoring topgrowth over root growth, but a possible indirect negative effect resulting from severe defoliation and a depression in root growth. This compounding effect will result in a short turfgrass root system going into the summer. Some nitrogen is needed in the spring for root and rhizome growth, as well as shoot growth. However, high nitrogen fertility rates in the spring will usually create more problems than it will solve. Liberal nitrogen fertilization also causes a lush, succulent plant growth that is characterized by decreased cell wall and cuticle thickness, increased cell size, and an increased level of plant tissue hydration. The increased cell size, and an increased level of plant tissue hydration. The thinner plant cell walls are most likely the result of more rapid plant growth and the production of fewer structural carbohydrates. This type of growth increases the severity of plant disease and lowers the hardiness of the plant to heat, cold, and drought. Lush, succulent tissue also contains high concentrations of nitrogen-rich storage compounds, which accumulate in guttation fluid (leaf exudates). The guttation fluid serves as an ideal medium for the enhancement of many turfgrass diseases. Thus, mismanagement of nitrogen in the spring can take the plant into summer in a soft growth condition in which it is more vulnerable to disease, heat, and drought.

Liberal nitrogen fertilization is known to increase the severity of Pythium, brownpatch, Fusarium blight (summer patch), stripe smut, snow mold, and Helminthosporium (leafspot) diseases (Vargas, 1975). Leafspot, a serious disease of both Kentucky bluegrass and bentgrass in the Midwest, is much more serious at high nitrogen levels, especially in the spring. Kentucky bluegrass varieties like Park, Kenblue, and Delta are very susceptible to leafspot. Many athletic fields and older turfgrass areas have been established to these common type Kentucky bluegrass varieties. Research (Turgeon and Meyer, 1974) has shown that the incidence of Fusarium blight in the summer is greater with increasing nitrogen application rates in the spring (Table 3). Nugget, Merion, Fylking, and Pennstar were highly susceptible to the disease when more than a total of 2 pounds of soluble nitrogen per 1,000 square feet was applied in the spring and early summer. Kenblue was affected by the disease at all the fertility levels. This information lends support to the practice of using moderate levels of nitrogen fertilizer in the spring. It more specifically suggests a critical limit of using no more than 2 pounds of total soluble nitrogen per 1,000 square feet in the spring to early summer (preferably no more than 1 to 1.5 lbs nitrogen per 1,000 ft). High nitrogen fertility in the spring can not only have detrimental effects in the spring but detrimental carryover in the summer as well.

Table 3. Effects of various spring fertilization rates and mowing heights on the incidence of Fusarium blight on several Kentucky bluegrass cultivars.

Fertilizer Rate (lb N/1,000 ft) May	June	Mowing height (inches)	Nuggett	Merion	Fylking	Pennstar	Kenblue
1	0	0.75	1.0	1.3	2.3	1.7	4.7
1	0	1.5	1.0	1.3	2.3	1.0	4.0
1	1	0.75	1.0	2.0	1.7	2.7	4.0
1	1	1.5	1.7	3.0	2.0	2.0	4.0
2	1	0.75	1.0	2.3	3.7	4.3	4.0
2	1	1.5	3.0	3.7	4.0	4.0	4.0
2	2	0.75	2.3	3.0	5.7	5.3	4.7
2	2	1.5	3.7	5.3	6.0	3.7	4.3

[a] Turgeon and Meyer, 1974
[b] A water-soluble nitrogen fertilizer was used
[c] Visual ratings of disease were made using a scale of 1 through 9' with 1 representing no apparent disease and 9 representing a complete blighting of the turf.

High nitrogen fertilization is also critical during the summer (Beard, 1973). As seasonal temperatures increase, photosynthesis of cool-season grasses decreases and respiration increases. Carbohydrates are consumed during respiration. Respiration is also known to increase with increasing nitrogen fertility levels. Thus, during periods of high temperature, liberal nitrogen fertilization may reduce carbohydrate reserves because of rapid growth and high respiration. Additional plant stress may result from lower photosynthetic rates. Because photosynthesis is low and respiration is high during the summer, nitrogen should be applied at low rates for cool-season turfgrasses.

LATE-SEASON NITROGEN FERTILIZATION

It has been pointed out that heavy nitrogen fertilization during the spring and summer is undesirable for cool season turfgrasses. Nitrogen fertilization has proven beneficial during the late fall (late season) on cool-season turfgrasses (Powell, Blazer and Schmidt). Decreased disease, improved stress tolerance, and increased rhizome and root growth are among several of the claimed advantages to the "late-season" nitrogen fertilization program. The late-season program is based on differences in optimum temperatures that exist between (1) root-rhizome growth versus shoot growth and (2) photosynthesis versus respiration.

Shoot and root growth of cool season turfgrasses occur most readily in the temperature ranges of 60-75 F and 50-65 F, respectively. Root growth of cool season grasses will continue at soil temperatures close to freezing

(Koski, 1983). Shoot growth will cease at higher temperatures than that for root growth. Late-season nitrogen feritilization capitalizes on this differential. Under late-season fertilization, nitrogen applications should be made when vertical shot growth has stopped, but the turf leaves are still green to produce carbohydrates via photosynthesis. Air temperatures of 45-50 F are usually necessary for vertical shoot growth stoppage. It is important to understand that since temperatures will be at a point causing stoppage of topgrowth, root, rhizomes and stolons will capitilize on any applied nitrogen. The carbohydrate produced will be more efficiently used for root, rhizome and stolon growth during the late fall and winter periods. It is critical that the nitrogen be applied prior to dormancy for maximum efficiency of applied nitrogen. Once the tissue has turned brown, photosynthesis will no longer occur. "Late-season" fertilization is not dormant fertilization.

During late fall, photosynthesis is higher than respiration for cool-season grasses. With green tissue, photosynthesis will occur readily at low temperatures. The high net photosynthesis during late season leads to maximum carbohydrate production and carbohydrate storage for reserves. The positive carbohydrate balance favors root and rhizome growth over topgrowth since air temperatures are well below that considered optimum for shoot growth.

Nitrogen applications during late season, if timed properly, will extend the greening of the turf later into the fall and winter. Spring green-up will normally occur earlier. The green turf is photosynthetically active favoring a positive carbohydrate balance. Late-season nitrogen fertilization; increases the "green growing" period of the turfgrass plant later into the fall and earlier in the spring. Physiologically, this is a positive agronomic practice. This is extremely desirable on athletic fields to lengthen the growing season (green growing period) especially during a period when traffic is not that intense. This practice essentially increases and enhances the recuperative potential time during nontraffic periods.

The most efficient nitrogen fertilizers for use in late-season fertilization programs are those independent of temperature for nitrogen release. Soil temperatures and microbial activity are low at this time of the year resulting in less efficiency from methylene urea and other temperature-dependent fertilizers. Urea and IBDU are fertilizers that are independent of temperature for nitrogen release and, therefore, make for excellent late-season nitrogen sources. IBDU, having a slow-release characteristic, will not cause surge growth even if misapplied (e.g., too early) in the late-season program. Nitrogen is a key component of turfgrass fertilization program. It has an influence on both the morphology and physiology of the turf plant. High quality turf exhibiting acceptable green color and density requires periodic applications of nitrogen. Nitrogen, however, is frequently referred to as the "TNT" of turfgrass fertilization programs. It can be just as detrimental as beneficial if it is mismanaged. Physiologically, the turf manager must maintain a good carbohydrate reserve. Proper timing and rate of application are important in successful long-term programs. Always remember: greener is not always better. A happy medium must be reached between agronomics and aesthetics.

Figure 1. Effect of nitrogen fertility on turfgrass diseases.

High Nitrogen	Low Nitrogen
Pythium	Dollarspot
Brown Patch	Red Thread
Fusarium Blight	Rust
Stripe Smut	
Snow Mold	
Leafspot	

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