

**Figure 1.** 'TifEagle' putting green turf quality and color in August, 2003. All received the same amount of nitrogen at  $\approx 5.6$  lbN/1,000 sq. ft./year applied biweekly. Primo was applied biweekly to plots A & C. A = 100% foliar fertilizers (a combination of Milliken liquid fertilizers of 4-0-1, 10-0-9, and 3-0-10) with 3 oz. primo/acre; B = 100% foliar fertilizers without Primo; C = 100% granular fertilizers with Primo 3 oz./acre; and D = 100% granular (18-3-18) fertilizer without Primo.

# Fertilizing Golf Greens

## Foliar versus Granular

By

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**G**olf course superintendents make decisions on an hourly basis that can affect their turf days, weeks and even months ahead. Deciding whether to use foliar or granular applications is likely to arise when superintendents consider agronomic issues, analyze fertilizer inventory, and plan budgets for the year ahead. The straight answer to the question of whether to use foliar versus granular, is both – when using a good combination of rates, timing, and season, and integrating applica-

tions with other programs such as plant growth regulators or fungicides. This article will address current research projects at Clemson University on foliar fertilization research on both creeping bentgrass and ultradwarf bermudagrass putting greens and offer perspectives and discussion on the subject based on literature and research.

## APPLICATION AND ABSORPTION

The subject of foliar fertilization automatically raises the question: How much liquid fertilizer do leaves actually absorb? It is a very reasonable question and points to uncertainty about the process of foliar absorption. When people ask this question, they need to consider the leaf morphology, the cuticle layer of the leaves, and the amount of fertilizer applied. In fact, when radio-labeled isotopes first became available in the 1950s for research, scientists already started to search for answers to this question by tracking the chemical movement in plant parts based on the labeled element's radioactivity. This method is still being used as an accurate research tool to track element distribution in turfgrasses and even in soils. The most commonly labeled plant nutrient has been  $^{15}\text{N}$ , which has a much longer half life and minimum hazardous impact in comparison with  $^{13}\text{N}$ , with a half life of only seven minutes. In addition to N, K, Fe, Mg, and Ca have been applied as liquid fertilizers to turfgrasses. The following provides general characteristics of foliar fertilization:

- Younger leaves have better foliar absorption.
- Lower (underneath) leaf surfaces (with more stomata) absorb more nutrients than upper side of the leaf.
- The first research on foliar absorption was documented in 1844.
- Neutral ion absorption seems more efficient than cation (positively charged ions) and anion (negatively charged ions) absorption.
- All 16 plant nutrients including some beneficial elements have been reported to be absorbed by leaves.
- Cuticle penetration is possible and is genetically regulated.

Several studies on both cool-season and warm-season turfgrasses indicate a foliar absorption rate normally between 30 and 60 percent of the nitrogen applied. For P and K, absorption efficien-

cies are even lower, between 20 and 30 percent. So another question arises: Where does the rest of the liquid fertilizer go? The rest may be left in the soil and the turf-soil system, lost by removal of clippings, or held in the thatch layer similarly to a granular fertilizer. However, the unabsorbed liquid fertilizer in the turf-soil system is still available to turfgrasses simply because it does not require a process to be dissolved in the soil solution before being absorbed by roots.

## ADVANTAGES AND DISADVANTAGES

The major advantages of foliar fertilization include requiring a lower total fertilizer input than a 100 percent granular fertilizer program, particularly for bermudagrass putting greens. Foliar fertilization also provides a quicker response than a granular fertilizer. Foliar fertilization by proper applications and practices will further minimize losses through leaching and runoff. Foliar fertilizer applications also have been reported to reduce foliar diseases. Significant concerns with foliar application include increased cost and labor, and it can burn the turf if applied at a high rate and the wrong time.

## ROOT GROWTH

Will foliar fertilization reduce root growth? The straight answer is no, although excessive nitrogen application will reduce root growth and promote foliar and above ground shoot growth. It seems logical that if the roots are not used for any nutrient absorption they will become smaller. The two aspects must be separated before the question is answered. First, excessive nitrogen application causes more carbohydrates produced through photosynthesis for shoot growth, leaving less carbohydrates for roots. Under stressful conditions, the situation is worsened and the turfgrass becomes weaker. Foliar nutrient absorption has much less impact on root growth because foliar absorption is more of a physical and chemical process than a biological process. Foliar nutrients are absorbed mainly through very small cracks of the cuticle layer in addition to stomata absorption. For nitrogen, urea ( $\text{NH}_2\text{CO}=\text{NH}_2$ ) is much more easily foliar-absorbed than nitrate ( $\text{NO}_3^-$ ) and ammonium ( $\text{NH}_4^+$ ) even though

the molecule sizes of the latter two are smaller than urea. Somehow, these small cracks do not let charged molecules, like nitrate and ammonium, pass through easily but do let neutrally charged molecules such as urea.

Nutrients in soils are taken up by roots through soil solutions. Whether enough nutrients exist in the soil solution or not, the water potential differences will keep the soil solution - including available nutrients - moving from the soil to the roots and into the upper parts of plants. Under slight to moderate water stress, root growth will be stimulated to search for more water. This is a drought resistant mechanism, or drought avoidance. In addition to water, many other factors have a greater impact on root growth than foliar fertilization.

## TIMING

Are there better times of the day to apply foliar fertilizers? Based on two studies carried out for two years for both creeping bentgrass (L93) and ultradwarf bermudagrass (TifEagle) greens at Clemson University, no differences in turf quality were found between applications at 10am versus applications at 5pm. However, evening applications are recommended for the following reasons:

Foliar nutrient absorption is more of a physical and chemical process (penetrating through the cuticle layer) than a biological process and it requires time. A minimum of three hours or more is needed to maximize foliar absorption. So, after a foliar application, an irrigation or rainfall should be avoided for three hours. For creeping bentgrass putting greens during summer, the first syringing of the day may be applied as early as late morning. After morning mowing, this may leave insufficient time for foliar fertilization. If a foliar application is conducted in the late morning, rising day temperatures will reduce foliar absorption efficiency and may increase burn potential to the turf since more salts are in contact with the leaf surface. Most forms of N foliar fertilizer are urea and the heat will promote volatilization losses. Still, turfgrass managers have practiced late morning foliar fertilizer application for years with little problems during the summer months. This is probably due ►

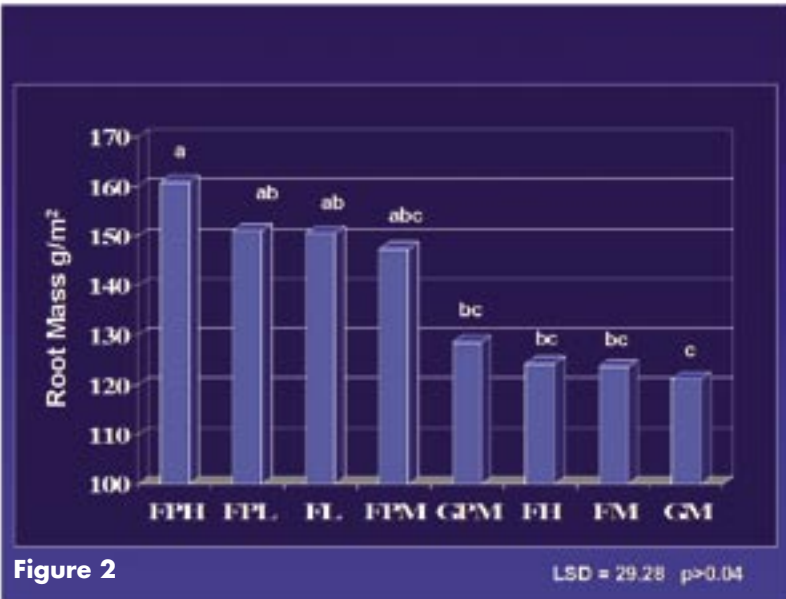


Figure 2

LSD = 29.28 p > 0.04

Rate (lb N/1,000 sq. ft./year)	Form	Rating (1-9)
2.6	100% Liquid	6.7 c
2.6	50% Liquid/50% Granular	6.7 c
2.6	100% Granular	6.5 d
3.9	100% Liquid	7.5 a
3.9	50% Liquid/50% Granular	7.2 b
3.9	100% Granular	6.8 c
	LSD	0.1005

Figure 3

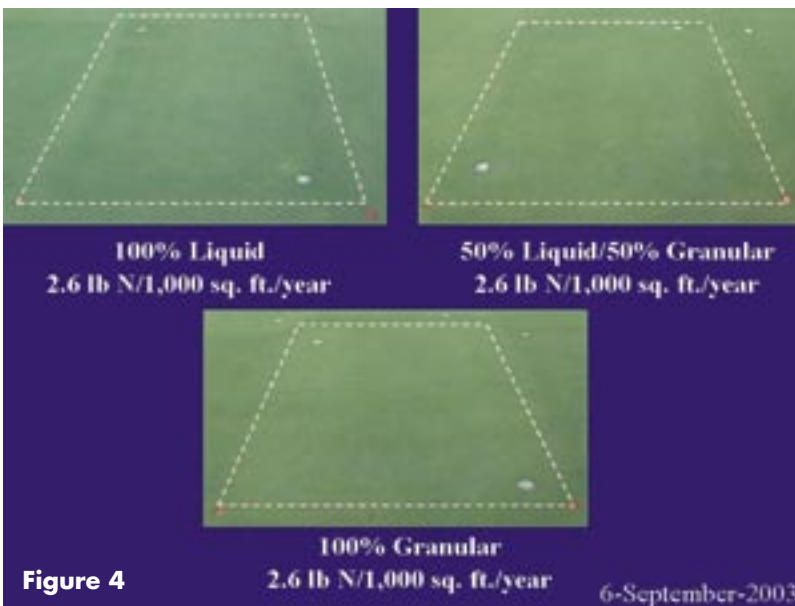


Figure 4

2.6 lb N/1,000 sq. ft./year

6-September-2003

Figure 2. Dry root mass of 'TifEagle' putting green at a mowing height of 1/8" treated with different levels of foliar liquid fertilizers and a granular fertilizer in 2003. The graph shows the average of root samples collected in June, August, and October:

**FPH** = 100% foliar fertilizer (a combination of Miliken liquid fertilizers of 4-0-1, 10-0-9, 3-0-10) at an annual rate of 7.2 N lb/1,000 sq. ft./year with a Primo rate of 3 oz./acre applied biweekly.

**FPL** = 100% foliar fertilizer at an annual rate of 4.0 N lb/1,000 sq. ft./year with a Primo rate of 3 oz./acre applied biweekly.

**FL** = 100% foliar fertilizer at an annual rate of 4.0 N lb/1,000 sq. ft./year without Primo

**FPM** = 100% foliar fertilizer at an annual rate of 5.6 N lb/1,000 sq. ft./year with a Primo rate of 3 oz./acre applied biweekly.

**GPM** = 100% Granular fertilizer (18-3-18) at an annual rate of 5.6 N lb/1,000 sq. ft./year with a Primo rate of 3 oz./acre applied biweekly.

**FM** = 100% foliar fertilizer at an annual rate of 5.6 N lb/1,000 sq. ft./year without Primo

**GM** = 100% Granular fertilizer at an annual rate of 5.6 N lb/1,000 sq. ft./year without Primo

Figure 3. 'L-93' creeping bentgrass putting green turf quality and color in fall 2003 and 2004. The fertilizers were applied biweekly as 100% foliar fertilizers (a combination of Progress Turf Inc. liquid fertilizers of 10-3-5 and 5-0-7); 50% liquid/50% granular as a combination of Progress Turf Inc. liquid fertilizers of 10-3-5 and 5-0-7 plus 18-3-18 granular fertilizer; and 100% granular (18-3-18) fertilizer.

Figure 4. 'L-93' creeping bentgrass putting green turf quality and color in summer of 2003. The fertilizers were applied biweekly as 100% foliar fertilizers (a combination of Progress Turf Inc. liquid fertilizers of 10-3-5 and 5-0-7); 50% liquid/50% granular as a combination of Progress Turf Inc. liquid fertilizers of 10-3-5 and 5-0-7 plus 18-3-18 granular fertilizer; and 100% granular (18-3-18) fertilizer.

to syringing practice that washes the foliar fertilizer into the soil with roots eventually absorbing it. This may be another advantage to foliar fertilization because foliar applications provide a “second chance” for plants to access the material. However, volatilization losses and varying the time length between foliar application and the first irrigation afterwards deserve more attention and research.

Secondly, when heavy dews exist, foliar fertilization along with a foliar absorbed plant growth regulator such as Primo, is not recommended. Without a mowing first, heavy dews exist as water droplets on the leaf surface causing immediate runoff of applied liquids from leaves. A very dry leaf surface does not help foliar absorption either. A slightly moist surface is ideal. Finally, during the evening, more stomata are typically open which increases the chances for foliar absorption.

**BEST FOLIAR PRACTICES - ULTRADWARFS**

The significant difference noticed in our two studies on TifEagle bermudagrass putting greens was the reduced total input of N using foliar fertilization. By using a total of 7.2 lbs N/1,000 sq. ft./year, the turf quality was always seven or above based on a one to nine scale (1 = brown turf and 9 = perfect green turf). The best single rate for TifEagle was between 0.2 to 0.4 lb N/1,000 sq. ft. every 10 to 14 days during the growing season. A combination tank mix of one to two oz./acre of Primo is highly recommended (Fig. 1 and 2). Combing several foliar fertilizers plus micro-nutrients is also highly recommended.

**BEST FOLIAR PRACTICES - BENTGRASS**

The best foliar fertilization practice with foliar applications for creeping bentgrass putting greens includes proper rate and frequent application, in combination with other practices. The best single rate of foliar application is between 0.1 to 0.2 lb N/1,000 sq. ft. with a frequency of 10 to 14 days (Fig. 3 and 4). During the summer, the rate should be reduced to 0.1 lb N/1,000 sq. ft. to reduce summer stress. Like bermudagrass, with creeping bentgrass, combinations with different

nutrients, particularly micro-nutrients, are highly recommended. During the two-year study, a tank mix with Primo (four to six oz./acre every two weeks) enhanced turf quality and slightly promoted root growth. Avoiding mid-day foliar applications during summer months and a combination of several foliar fertilizers are also recommended.

**WHAT ABOUT GRANULAR**

Should We Forget About Granular Fertilizers on Putting Greens? Based on our research results, we cannot provide a definitive answer to this question since all treatments of 100 percent foliar liquid fertilizer, 50/50 percent foliar and granular, and 100 percent granular provided acceptable turf quality for both creeping bentgrass and ultradwarf bermudagrass putting greens. However, 100 percent foliar fertilization did provide higher turf quality when compared with the same rate of input of granular fertilizers for both creeping bentgrass and bermudagrass putting greens. One reason might be that foliar fertilization provided more uniform coverage than the granular fertilization or the next mowing might have removed some granular fertilizers. Granular fertilizers require less labor and their slow releasing effects mean longer availability in the soil, which liquid foliar fertilizers do not have, particularly for creeping bentgrass putting greens. Deciding which method to use will also depend on the labor, fuel, and budget conditions at each golf course. Our recommendations are to combine both methods rather than relying on one method exclusively. During the summer months, foliar liquid fertilization at lower rate with high frequency is highly recommended. During the fall and early spring growing seasons, a slower release granular fertilizer provides an economic alternative. For soils with lower P concentration or under acidic conditions, granular P application is recommended to efficiently correct the problem of P deficiency. ■

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