Golfdom'S PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

NITROGEN UPTAKE

# Low-Temperature Nitrogen Uptake

*By Daniel T. Lloyd, Douglas Soldat, Ph.D., and John Stier, Ph.D.*

In temperate climates, fall is widely considered the most important time for nitrogen fertilization. Half of the nitrogen applied annually is typically applied in the fall. (Bauer et al., 2012). The belief is that fall's cooler temperatures allow more assimilated nitrogen to be used for carbohydrate accumulation and root and rhizome development instead of being partitioned into shoot growth (Bowman, 2003).

However, research evaluating the benefits of late-fall nitrogen fertilization has yielded mixed results — likely due to regional, temporal and climatic variability (Bauer et al., 2012). Improved color responses in the fall, winter or spring have been observed consistently in the Midwest and Northwest and along the East Coast. Root growth response to late-fall nitrogen fertilization has been less consistent. Some researchers have found greater root mass in the fall or spring, while others have found negative or insignificant root responses to nitrogen applied in the fall.

Just how much turfgrass can assimilate nitrogen in late fall is unclear. Research has shown that for many other plants, nitrogen uptake is greatly inhibited in temperatures below those of optimal growth, due to limited xylem flow and down-regulated transporters responding to decreased plant demand (Dubey and Pessarakli, 2002).

To what extent low temperatures inhibit a turfgrass's nitrogen uptake often depends on environmental factors and the turfgrass species. When turfgrass uptake and nitrogen immobilization decline, high rates of nitrogen fertilization increase the potential for fertilizer loss through denitrification and leaching — especially considering late fall often brings high precipitation and low evapotranspiration (ET) rates. Excess nitrogen fertilization in late fall therefore can pose an economic and environmental burden.

Much of the research on late-fall nitrogen fertilization was performed in field settings. That fact may limit the transferability of the results. In fact, no controlled environment research on evaluating low-temperature nitrogen uptake, metabolism and utilization of turfgrass could be found. Controlled environment research on the response differences between nitrogen rate, application timing and turfgrass species in cool temperatures also couldn't be found.

Because fall fertilization is important, the agronomic significance of it should be evaluated through controlled environment research accounting for climatic and spatial variables — including temperature, photoperiod, nitrogen rate and turfgrass

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PHOTO COURTESY: DOUGLAS SOLDAT, PH.D.

***With a climate-controlled environment, researchers could observe responses to various cool-season turfgrass species to variable nitrogen rates and temperature regimens.***

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species composition.

This study aimed to evaluate nitrogen uptake potential and utilization in a climate-controlled environment to see the responses of various cool-season turfgrass species to variable nitrogen rates and temperature regimens.

## Materials and methods

"Midnight" Kentucky bluegrass, "Penncross" creeping bentgrass and "True Putt" annual bluegrass were established from seed in a greenhouse set to 75 F /64 F day/night temperatures with a photoperiod of 14 hours. Plants were grown in a USGA-recommended root zone mix in 4-inch diameter, 12-inch depth PVC tubes. Full details of the grow-in program are reported by Lloyd et al. (2011).

Plants were clipped using hand shears three times weekly to the height of 0.5 inch until nitrogen treatments were applied. Fourteen weeks after seeding, the plants were transferred from the greenhouse into a growth chamber for cool temperature acclimation.

The three grass species were fertilized with one of four nitrogen treatments (0, 0.5, 1.0, and 2.0 lbs. N/1,000 sq. ft.) and acclimated to one of three simulated climate regimens corresponding to September 15$^{th}$ (with an average high of 72 F, an average low of 52 F and 12.5 hours of light); October 15$^{th}$ (with an average high of 59 F, an average low of 44 F and 11 hours of light); and November 15$^{th}$ (with an average high of 40 F, an average low of 27 F and 9.6 hours of light). They were fertilized in Madison, Wis. and the temperatures were based on 40-year averages.

Treatments were arranged in a randomized design in climate-controlled chambers at the University of Wisconsin-Madison Biotron Facility. The experiment was conducted twice under identical conditions. Upon entering the growth chamber, plants were allowed to acclimate for 16 days through staggered decreasing temperature regimens, where the temperature was lowered by 4 F to 7 F every four days until temperature reached the appropriate set points. Following the acclimation period, plants were fertilized with one of the four nitrogen rates using a liquid solution of $^{15}$N-labeled ammonium sulfate (10 atom % $^{15}$N). Plants were irrigated after application

**TABLE 1:** ABOVEGROUND BIOMASS AS AFFECTED BY TEMPERATURE AND NITROGEN

| Timing | Nitrogen application rate | | | |
|---|---|---|---|---|
| | 0 lbs./ 1,000 sq. ft. | 0.5 lbs./ 1,000 sq. ft. | 1.0 lbs./ 1,000 sq. ft. | 2.0 lbs./ 1,000 sq. ft. |
| *Run 1* | $g\ m^{-2}$ | | | |
| Sept. | 178 C | 240 B | 254 AB | 306 A |
| Oct. | 225 BC | 217 BC | 225 BC | 217 BC |
| Nov. | 217 BC | 220 BC | 227 BC | 240 BC |
| *Run 2* | $g\ m^{-2}$ | | | |
| Sept. | 249 CD | 277 BC | 321 AB | 348 A |
| Oct. | 215 DE | 220 DE | 232 CDE | 235 CDE |
| Nov. | 183 EF | 188 EF | 185 EF | 158 F |

***Aboveground biomass was harvested 10 days following nitrogen application. Temperature regimens correspond to Sept., Oct., and Nov. 15th in Madison, Wis. Different letters within runs indicate statistical significance at the 0.05 level according to Tukey's HSD.***

**TABLE 2:** ROOT BIOMASS AS AFFECTED BY TEMPERATURE AND NITROGEN

| Timing | Nitrogen application rate | | | |
|---|---|---|---|---|
| | 0 lbs./ 1,000 sq. ft. | 0.5 lbs./ 1,000 sq. ft. | 1.0 lbs./ 1,000 sq. ft. | 2.0 lbs./ 1,000 sq. ft. |
| *Run 1* | $g\ m^{-2}$ | | | |
| Sept. | 192 CDEF | 220 BCDEF | 179 EF | 159 F |
| Oct. | 231 ABCDE | 179 EF | 183 DEF | 159 F |
| Nov. | 253 ABC | 227 AB | 318 A | 253 ABCD |
| *Run 2* | $g\ m^{-2}$ | | | |
| Sept. | 231 A | 253 A | 220 A | 215 A |
| Oct. | 271 A | 247 A | 247 A | 271 A |
| Nov. | 247 A | 210 A | 259 A | 247 A |

***Temperature regimens correspond to Sept., Oct., and Nov. 15th in Madison, Wis. Roots were harvested 10 days following nitrogen application. Different letters within runs indicate statistical significance at the 0.05 level of log transformed values according to Tukey's HSD.***

and then every three days to 80 percent of pot moisture capacity based on weight to eliminate the potential for leaching losses.

Plants were destructively harvested 10 days after labeled nitrogen applications. They were separated into root biomass and verdure biomass (shoots and crowns) for isotopic $^{15}N$ analysis using an automated carbon-nitrogen analyzer.

The experiment was a completely randomized design with three replications. It was conducted twice, in separate "runs," which were treated similarly to a year or location effect in the statistical model. This summary reports the first of the "runs." For more information on the statistical methods and full results see Lloyd et al. (2011).

## Results and discussion

There were very few important differences in plant responses to temperature and nitrogen among the three species. Therefore, for brevity, we will discuss the responses of the three grasses averaged together. We observed a lack of growth response to nitrogen in October and November temperature regimens (Table 1), consistent with previous research suggesting a minimal shoot growth response to nitrogen in temperatures below 50 F (Powell et al., 1967; Wilkinson and Duff, 1972).

As noted in the introduction, the convention for the past several decades has been to recommend nitrogen application in the fall

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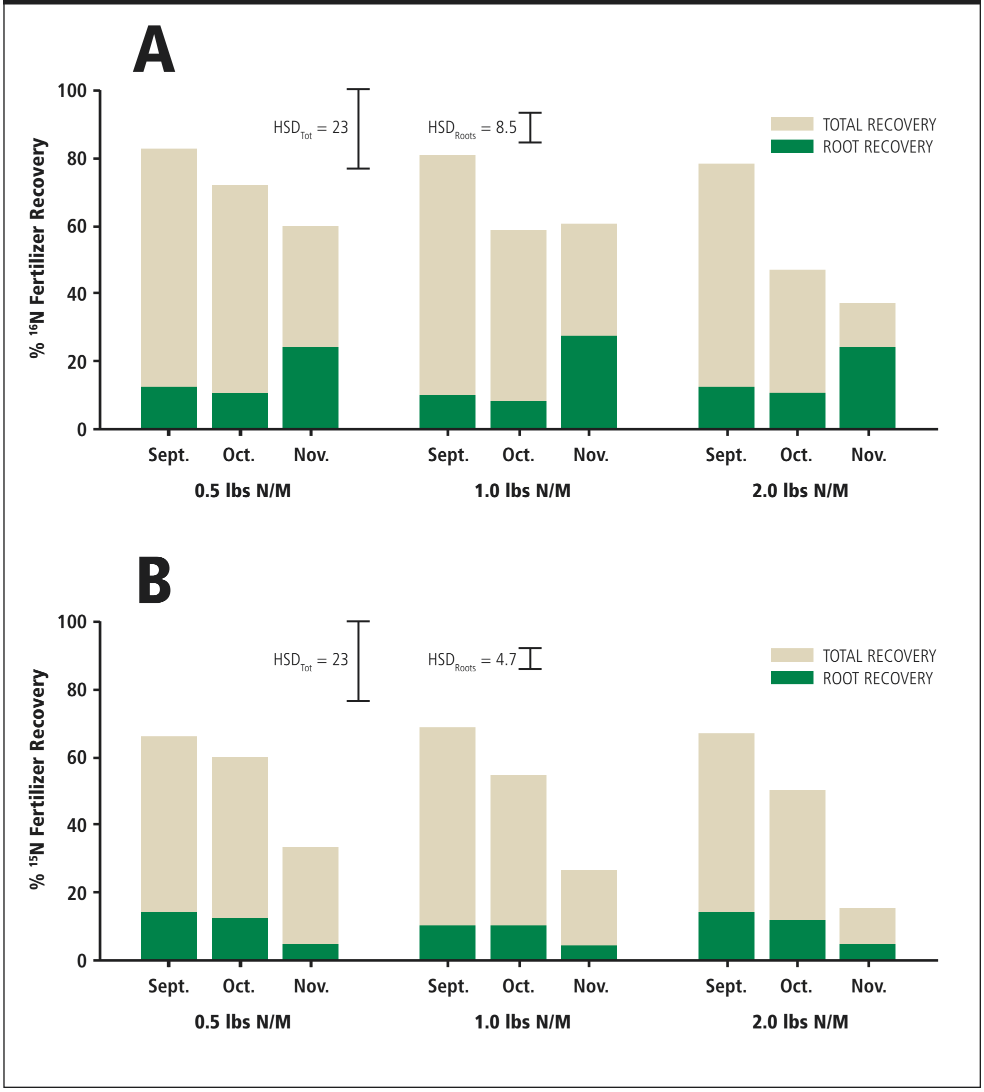
**FIGURE 1:** RUNS NO. 1 AND NO. 2




*Effect of temperature regimen and nitrogen application rate on $^{15}$N fertilizer recovery in roots and roots + verdure (total) for (A) run No. 1 and (B) run No. 2. Roots and verdure were harvested 10 days following nitrogen application. Temperature regimens correspond to Sept., Oct., and Nov. 15th in Madison, Wis.*

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around the time when active shoot growth stops. Our results indicate that actively growing turfgrasses, such as in the September treatment, absorb applied nitrogen very efficiently (65 percent to 83 percent of applied nitrogen) regardless of nitrogen rate (Fig. 1). Fertilizing when shoot growth becomes unresponsive to nitrogen application (in October) still was relatively efficient (46 percent to 72 percent of applied nitrogen), especially at the lowest application rate. However, fertilizing when air temperatures approach 32 F resulted in low and variable uptake of applied nitrogen (15 percent to 60 percent of applied nitrogen).

These results build upon the work of Bowman et al. (1989), who quantified the uptake potential of cool-season grasses by monitoring the rapid depletion in the soil of applied fertilizer. That study demonstrated the nitrogen uptake potential under ideal growing conditions in the field, while our study demonstrated the extent of nitrogen uptake under cool temperatures.

Root accumulation of $^{15}$N was markedly different between runs. In the first run, we observed significantly greater recovery of

$^{15}N$ in the November regimen compared to the September and October regimens (Fig. 1A). However, the opposite occurred in run No. 2 (Fig 1B). Root fertilizer nitrogen concentrations accounted for an average of 17 percent of total nitrogen taken up, averaging 0.1 lbs. nitrogen per 1,000 sq. ft. (data not shown).

Additionally, root growth was not consistently affected by nitrogen application rates (Table 2), indicating that although root growth may increase in response to cooler soil temperatures, this trend is not stimulated further through nitrogen fertilization.

Our finding is consistent with previous research (Powell et al., 1967; Kussow, 1988; Mangiafico and Guillard, 2006). It may not be surprising that we found few differences in root growth among the treatments, because only 10 days passed between application and harvest. While additional longer-term or field research would be desirable to test the hypothesis that fall nitrogen does not affect root growth, our data preliminarily indicate that nitrogen applied at these rates in these temperature regimens has little effect on short-term root growth.

> When turfgrass uptake and nitrogen immobilization decline, high rates of nitrogen fertilization increase the potential for fertilizer loss through denitrification and leaching.

We were unable to conclusively document the effect of nitrogen partitioning between shoots and roots for nitrogen applications in cold temperatures. It appears that shoot: root partitioning was not significantly different between the September and October temperature regimens. However, in run No. 1, strong partitioning of nitrogen to roots was observed in November, while in run No. 2 it wasn't.

## Conclusion

Our results suggest that some of the widely held views on the importance of fall fertilization may not be as understood as thought. The nitrogen uptake capacity of creeping bentgrass, annual bluegrass and Kentucky bluegrass declines substantially as temperatures decrease, although nitrogen uptake potential appears to be relatively high after shoot growth stops.

Waiting after this period greatly reduces nitrogen uptake potential. Because of the increased risk of fall nitrogen loss in humid, temperate regions with seasonally high precipitation rates and low evapotranspiration rates, agronomic recommendations for late-fall fertilization need to be re-evaluated. Additional field research is required to confirm the results of this controlled environment evaluation.

Editor's note: The units for aboveground and root biomass in Tables 1 and 2 were intentionally left as grams/metered squared.

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