# FERTILIZER NITROGEN USE EFFICIENCY AND FATE IN TALL FESCUE SEED PRODUCTION

*E.C. Verhoeven and D.R. Carrijo*

**Introduction**

Optimizing the timing and rate of fertilizer nitrogen (N) inputs is critical to achieving high crop yields and profitability, while minimizing the risk of environmental losses. In years with mild or warm January temperatures, the OSU-recommended growing degree day (GDD) mark to begin fertilization can be reached as early as the end of January for tall fescue (200 GDD). While extensive work has been done to develop current OSU fertilizer recommendations for timing and rate of spring N, there have been questions about how much early-season (January) N may be taken up by the plant, remain in the soil, or be lost via leaching when we have early GDD accumulation followed by a period of cooler temperatures prior to rapid growth later in the spring. Past research has shown that peak N uptake typically occurs in late March to early April in tall fescue (Anderson et al., 2014).

While developing recommendations to maximize plant N uptake, it is also critical to minimize losses of N into the environment. To date, previous studies in the Willamette Valley have primarily focused on N fertilizer fate/loss in the Calapooia watershed in the southern Willamette Valley. This focus was due to the discovery of nitrate levels in wells and groundwater in portions of the Calapooia watershed that persistently exceeded the EPA drinking water standard of 10 mg/L. As a result, a groundwater management area was declared in 2004.

Research in this area has found that nitrate-N leaching can vary widely among crops, years, and fields. A study that included fields in vegetable seed, hazelnut, blueberry, mint, and grass seed production estimated annual nitrate-N leaching rates between 0.5 to more than 250 lb $ac^{-1}$ (Compton et al., 2021). Within this study, five grass seed fields were included (an annual ryegrass field and two perennial and tall fescue fields). Annual nitrate leaching from the grass seed fields ranged from 9 to 134 lb $ac^{-1}$ $yr^{-1}$ and occurred mainly in the fall and early winter. Similarly, another study that looked at modeled crop N losses across the Calapooia watershed found that nitrate losses and export to streams were highest in the fall and winter (Lin et al., 2019).

The Calapooia watershed is characterized by a higher proportion of poorly drained soils than are other parts of the Willamette Valley, which may affect leaching, runoff, and N losses in the area. More research is needed in the Willamette Valley, across a broader diversity of soils, to better understand tall fescue plant N utilization and potential N loss from early-season fertilizer applications, as well as postharvest losses during the subsequent fall and early winter. In addition, a need exists to generate more comprehensive data on tall fescue N use efficiency (NUE, i.e., the percentage of fertilizer N recovered in above-ground plant material at harvest) and N fate under typical management systems for tall fescue seed production.

Various methods exist to calculate the NUE of a cropping system and to evaluate N loss from the soil. In this study, we utilized $^{15}N$ isotope-labeled urea fertilizer, which acts like a dye and allows the tracing of N in the plant and soil system. In this method, any applied N not recovered in the plant or crop rooting zone is assumed to be lost into the environment (leaching, surface runoff, volatilization, or denitrification). Estimates of NUE in major commodity crops (corn, wheat, and rice) range between 30 and 50%, with estimated annual fertilizer losses often in the range of 10–30% (Quan et al., 2021; Zhang et al., 2021). Better estimates of NUE in current grass seed production systems will help growers better understand their crops' current NUE and whether there is potential for improvement.

The overall objectives of this study were two-fold:

- To determine the optimal timing for spring N application to tall fescue in order to maximize uptake and minimize losses.
- To determine the NUE of typical tall fescue systems, across different soil types of the Willamette Valley, and to estimate environmental losses during the growing season and in the fall after harvest.

**Materials and Methods**

Three identical on-farm trials were conducted in second-year tall fescue fields, representing two relatively well-drained soils and one poorly drained soil (Table 1). The different levels of soil drainage were chosen to represent typical tall fescue systems in the Willamette Valley. At each field site, plots (12 feet x 4 feet) were established for application of the labeled fertilizer.

Table 1. Mapped soil series, soil drainage class, and baseline properties of each study site.[1]

| Site | Soil series | Soil drainage | Soil sample depth | Sand | Silt | Clay | C | N | pH | Bulk density |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (%) | (%) | (%) | (%) | (%) | (1:1 $H_2O$) | ($g/cm^3$) |
| St. Paul | Woodburn | Moderately well | 0–6 in | 15 | 63 | 22 | 1.97 | 0.16 | 6.94 | 1.38 |
| | | drained | 6–12 in | 15 | 64 | 22 | 1.47 | 0.14 | 6.60 | 1.28 |
| Silverton | Salkum | Well drained | 0–6 in | 23 | 51 | 26 | 3.09 | 0.23 | 7.03 | 1.24 |
| | | | 6–12 in | 20 | 48 | 32 | 1.81 | 0.14 | 6.19 | 1.29 |
| Shedd | Holcomb/ | Somewhat to | 0–6 in | 10 | 66 | 24 | 2.80 | 0.23 | 6.71 | 1.28 |
| | Dayton | poorly drained | 6–12 in | 12 | 62 | 26 | 2.03 | 0.18 | 5.84 | 1.26 |

[1]Soil properties were determined from composite samples taken at each site and analyzed at the Soil Health Lab at Oregon State University.

A $^{15}N$-labeled urea fertilizer solution was applied at a total rate of 140 lb N/acre at three timings: early (230 GDD), late (365 GDD), and a split application (70 lb N/acre at both 230 and 365 GDD). According to industry and OSU standard practices, GDD was calculated beginning January 1 using a base temperature of 0°C. Different concentrations of fertilizer solutions were made by dissolving urea enriched with 2.3 atom% of $^{15}N$ in deionized water. A total of 1 gal was applied to each plot using a fine-nozzle watering can. At each site, growers also applied 40–60 lb N/acre in the fall following harvest as unlabeled urea.

Plant (above-ground) and soil (0- to 6-inch and 6- to 12-inch) samples were taken monthly at four dates until harvest. Final harvest samples were taken at physiological maturity (June 22–June 24, 2020). All sites were sampled again in January 2021, referred to as “postharvest.” The harvest and postharvest sampling included sampling of the roots + crown down to 6 inches and an additional deeper soil sample at 12–18 inches. The postharvest sampling in January detected the presence of only the labeled fertilizer applied the previous spring.

Fertilizer recovery in plants and soil was determined with standard calculations for isotope tracer studies, which enabled the amount of fertilizer to be determined in the soil and plant at each sampling date. Climate data associated with each site was drawn from the PRISM Climate Group. The PRISM Climate Group uses spatial interpolation to model weather variables at a 4-km grid scale from local weather station data. All data were analyzed with a linear mixed effects model using repeated measures.

**Results and Discussion**

Across all three sites, there was no effect of fertilizer application timing (early, late, or split) on total plant N uptake (Figure 1) or estimated fertilizer N losses (data not shown). We also observed few differences among the sites, and there was no effect of soil type or drainage on plant N uptake or N losses in the year of the study (data not shown). Both of these results were in contrast to our hypothesis that increased N loss would result from early N application and would be more extensive in poorly drained soil.

On average, across sites and treatments, 57% of spring-applied N was recovered in the above-ground biomass at harvest, equating to NUE of 57% (Table 2). For most commodity grain systems, the NUE is generally between 30 and 50%, so the tall fescue systems in this study were comparatively more efficient at utilizing N fertilizer.

It should be noted that in the year of study February was quite dry, with about 3 inches less precipitation than normal (about half of the normal amount). This may have reduced leaching and runoff. Weather conditions in February are considered favorable for leaching loss of early N applications because plant growth is still relatively low. However, we believe the relatively high NUE comes not from uncharacteristically low losses but from the ability of tall fescue to scavenge soil N due to an extensive root system and to the capacity of Willamette Valley soils to retain and cycle N due to their relatively high organic matter content.

By harvest, 57% of the total fertilizer N applied was contained in the above-ground plant tissue, with 9% in

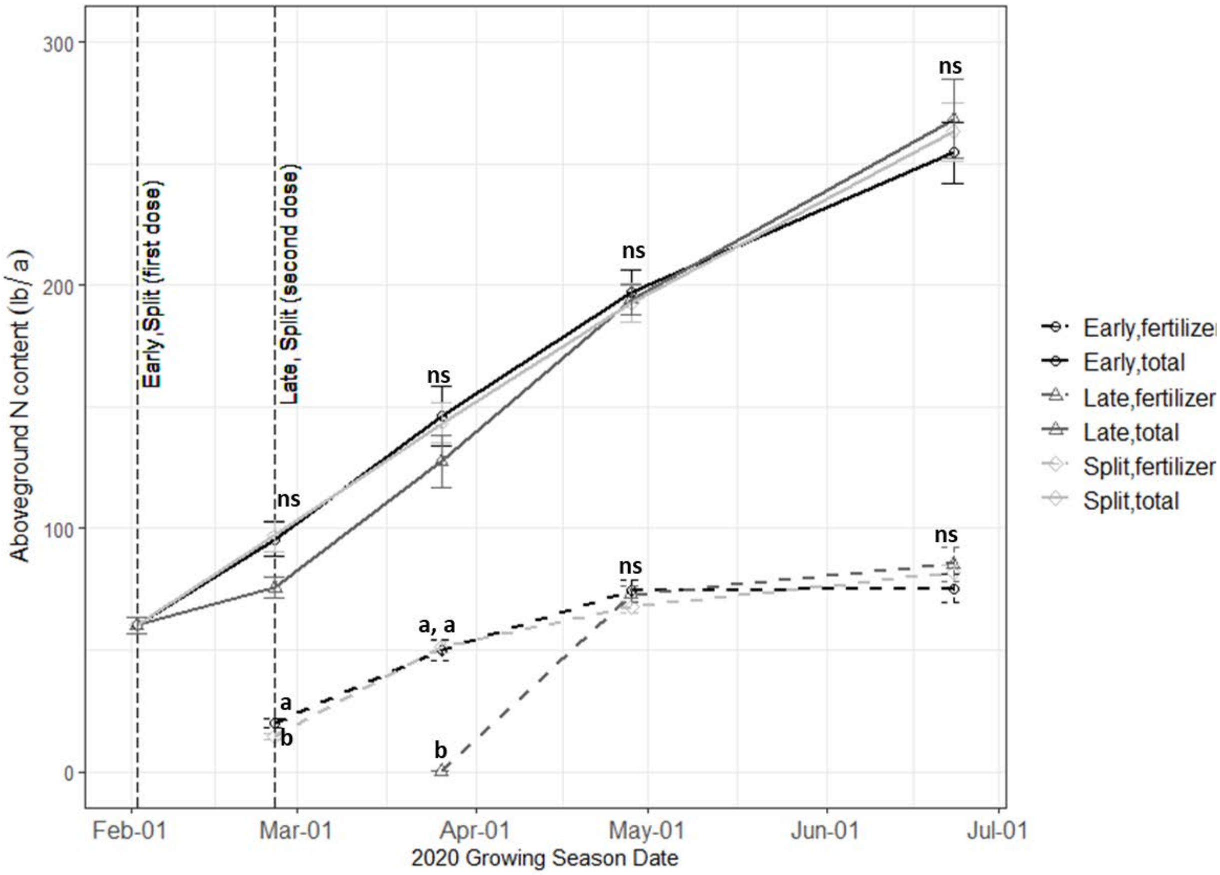


Figure 1. Total (solid lines) and fertilizer-derived nitrogen (N) (dashed lines) content in above-ground biomass over time. Values were averaged across the three locations, as there were no interactions between treatment, location, and time. Vertical lines indicate N fertilizer timings; N applications were made immediately after sampling on each date. At each sampling time, different letters within total or fertilizer-derived N indicate significant differences ($P < 0.05$) between treatments. Error bars indicate standard error of means. ns = no significant difference.

roots + crown, and 24% in the soil (0–18 inches). Most of the applied N remained in the top 6 inches of soil at harvest (Table 2). While 57% of applied N ended up in the above-ground biomass at harvest, this represented only 31% of the total N in the above-ground plant biomass and indicates that the soil was able to provide the majority of plant N needs, almost 70%. The high capacity of soils in this study to mineralize and supply N may be due to relatively high organic matter and to a buildup of organic N.

Plant uptake of applied N leveled off by the end of April, and most N accumulation in plant biomass after May appeared to be supplied by mineralization from soil organic matter (Figure 1). The ability of soil to supply N depends on the amount of total or organic N in

Table 2. Quantity and percent of applied fertilizer nitrogen (N) in each measured component of the system at harvest.

| Component | Applied N | % of total applied N |
|---|---|---|
| | (lb/a) | (%) |
| Above-ground biomass (leaves + seeds) | 80 | 57 |
| Crown + roots | 13 | 9 |
| Soil (0–6 in) | 22 | 16 |
| Soil (6–12 in) | 9 | 6 |
| Soil (12–18 in) | 2 | 2 |
| Estimated loss | 14 | 10 |

the soil and the rate at which this N is mineralized and converted to plant-available forms by microorganisms.

Nitrogen mineralization rates were not measured in this study, but it appears that mineralization rates must have increased in May as soil temperatures warmed because uptake and accumulation of N in above-ground biomass continued after uptake of labeled fertilizer N reached a plateau. Above-ground biomass N accumulation was slightly reduced in the late application treatment in March and April, but these reductions did not persist later into the season (Figure 1). Seed yields were not measured in this study, but there were no differences in total above-ground biomass at harvest due to N application timing.

At harvest, only 10% of applied N could not be recovered and was considered lost to the environment through leaching, denitrification, or volatilization (Table 2).

Although N leaching was not directly measured in this study, we did not see evidence of appreciable applied N movement down the soil profile, and we conclude that leaching of spring-applied N was low. Previous research has shown that applied N that remains in the soil after harvest may be lost through surface runoff or leaching from fall and winter precipitation (Lin et al., 2019; Compton et al., 2021). We did not find that to be the case in this study. When we sampled again in January 2021, the same amount of fertilizer N that was in the system at harvest remained in the system approximately 1 year after fertilizer application.

As noted above, 24% of fertilizer N remained in the soil at harvest, most of it in the top 6 inches (Table 2). This and the fact that the soil could supply the majority of plant N uptake indicates there may be potential to reduce fertilizer N inputs without reducing yields in established tall fescue. Timing of N application had no effect on N uptake or loss, nor was it influenced by study site (poorly to well-drained soils). Overall, the results from this study suggest flexibility for N management in tall fescue seed production regarding early applications and the potential to reduce application rates.

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