AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
FUNDING CYCLE 2020 – 2022

TITLE: Tracking nitrogen fertilizer fate in tall fescue production

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COOPERATORS:

SUMMARY/ABSTRACT:
Optimal stewardship of fertilizer nitrogen (N) is necessary to achieve high yields and reduce the impacts of reactive N into the environment. However, insufficient information on fertilizer fate and N use efficiency is available for grass seed crops particularly when changing weather patterns can lead to increasingly early spring N applications. A field trial using ^{15}N labelled urea applied at three spring timings in tall fescue was implemented at three locations in the Willamette Valley, representing different soil types and drainage levels. The efficiency of fertilizer nitrogen recovery (RE_N) was not affected by application timing or location and averaged 57% across sites and treatments. Overall, 91% of fertilizer was recovered in the soil-plant system at harvest, with 24% remaining in the soil (0-45cm), and 10% remaining in root + crown biomass. Similar quantities of ^{15}N fertilizer were recovered six months post-harvest, indicating little to no post-harvest N losses in the year of study. Only 31% of aboveground plant N uptake at harvest could be traced to the spring fertilizer applications, indicating that soil N sources supplied the majority of plant N uptake. This result, along with the fact that 24% of fertilizer N remained in the soil at harvest, suggest that fertilizer rates could be reduced in these systems. The high capacity of the soil to supply N could be due to one or a combination of factors such as: historical N applications that have elevated organic soil N and N cycling, relatively high OM and microbial activity, or the ability of roots and crown to supply N.

OBJECTIVES:

1. Determine fertilizer nitrogen recovery in plant biomass and soil at the end of the growing season under three fertilizer application timing scenarios (main project, funded by OSC and Tall Fescue Commission)
2. ***Track the movement or fate of residual (post-harvest) fertilizer nitrogen into the subsequent growing season. Determine the amount of residual fertilizer that remains in the roots+crown, is used for crop growth the following season, or is lost in fall/winter (add-on to above, ARF funded portion of the project)***

PROCEDURES:
The main project was successfully implemented beginning in January 2020. Three replicated on-farm trials were implemented in the Willamette Valley, representing two relatively well drained soils and one poorly drained soil (Tables 1 and 2). The different levels of soil drainage were

intended to represent typical tall fescue systems in the Willamette Valley. At each field site, plots (12 x 4 ft) were established for application of the labeled fertilizer.

A ^{15}N labeled urea fertilizer was applied at a total seasonal rate of 140 lbs N/A at three timings: Early (230-250 GDD), Late (400-450 GDD) and a Split application (230-250; 400-450) (Table 3). Fertilizer application was achieved by dissolving 2% atom enriched ^{15}N urea into 15L of deionized water. Different strengths of solution were utilized to achieve rates of 140 lbs N/A for the Early and Late applications and 70+70 lbs N/A for the Split application treatment. Fertilizer was applied manually using a watering can with a fine nozzle (Figures 1 and 2).

Plant (aboveground) and soil (0-6” and 6-12”) samples were taken at five dates, corresponding to the Early (early February) and Late (early March) fertilization dates, and then the end of March, April and June (harvest). The harvest sampling included belowground (6-12“) plant samples and deep (12-18”) soil samples.

Table 1. Site soil characteristics

Location	Soil Series	Soil Drainage Class	Soil Type
St. Paul	Woodburn	Moderately well drained	Fine-silty, Mollisol
Silverton	Salkum	Well drained	Clayey, Ultisol
Tangent/Shedd	Holcomb/Dayton	Somewhat to poorly drained	Fine, Alfisol

Table 2. Baseline soil properties

Site	depth	sand	silt	clay	C	N	pH	Bulk density
		---------------------------% --------------------- ----					1:1 H_2O	(g/cm^3)
St. Paul	0-6"	15	63	22	1.97	0.16	6.94	1.38
	6-12"	15	64	22	1.47	0.14	6.6	1.28
Silverton	0-6"	23	51	26	3.09	0.23	7.03	1.24
	6-12"	20	48	32	1.81	0.14	6.19	1.29
Shedd	0-6"	10	66	24	2.80	0.23	6.71	1.28
	6-12"	12	62	26	2.03	0.18	5.84	1.26

Biomass samples from each plot were taken from miniplots (2.7 sq ft), which were centered on one or two rows, depending on the site (miniplot dimensions varied slightly to accommodate different row spacing at each site). A random miniplot was selected at each sampling point and marked with a flag to avoid repeated sampling. Biomass was scaled up to a per acre basis by calculating the length of row sampled relative to the total row length in a square acre given the row spacing. Climate data associated with each site was drawn from the PRISM Climate Group, which is modeled from local weather sites at a 4km grid scale.

At the time of biomass sampling, soil samples (six per miniplot) were taken from the miniplots using a 1”diameter soil core. The cores were evenly distributed across a row to ensure that the samples represented the range of soil from within the plant row to bare soil mid-row; the six cores were then combined for one composite sample per plot. From the composite samples, a subsample of fresh soil was used for inorganic nitrogen and we used our measured soil bulk density at each site to convert values to a lb N/A basis. The remaining sample was dried, ground and weighed for ^{15}N and total N analyses.

Plant and soil samples were oven-dried, ground and homogenized before being analyzed for total N concentration and ^{15}N atom% concentration at the OSU Staple Isotope Laboratory (http://stable-isotope.coas.oregonstate.edu). This aspect of the work has proved the most time consuming and laborious. Samples must be thoroughly ground to a powder while ensuring the sample remains completely homogenous and representative of the full sample, this requires the use of two mills and careful subsampling when moving to a smaller mill. Following grinding, samples were microbalanced into ~5mg (plant) or ~50 mg (soil) tin capsules (Figure 3).
N fertilizer recovery (FR, %) in plants and soil was calculated as:

$$FR_{plant,soil} = \frac{AE_{plant,soil}}{AE_{fertilizer}} \times \frac{TN_{plant,soil}}{FA}$$

where: AE = ^{15}N atom% excess (%), TN = total N (kg/ha) and FA = fertilizer applied (kg/ha).

AE was calculated as:

$$AE_{plant,soil,fertilizer} = AC_{plant,soil,fertilizer} - ACN_{plant,soil,fertilizer}$$

where AC = ^{15}N atom% concentration (%) and ACN = ^{15}N natural abundance (%).

TN was calculated as:

$$TN_{plant} = N_{plant} \times B_{plant}$$

$$TN_{soil} = N_{soil} \times BD \times SD \times 1000$$

where N = N concentration (g g^{-1}), B = biomass (kg ha^{-1}), BD = soil bulk density (kg m^{-3}), and SD = soil layer depth (m).

All sites were sampled again in January 2021 (funded by this grant), titled, “year 2”. Samples were taken of: soil 0-6”, soil 6-12”, soil 12-18”, above ground biomass, root + crown for ^{15}N fertilizer concentration. 180 samples in total. Biomass and soil processing was identical to our harvest sampling time point, as described above. The work specifically funded by this ARF grant consisted of sample preparation of year 1 and year 2 samples of plant and soil material for 15N analysis (multiples stages of grinding and microbalancing, Fig. 1) and root washing.

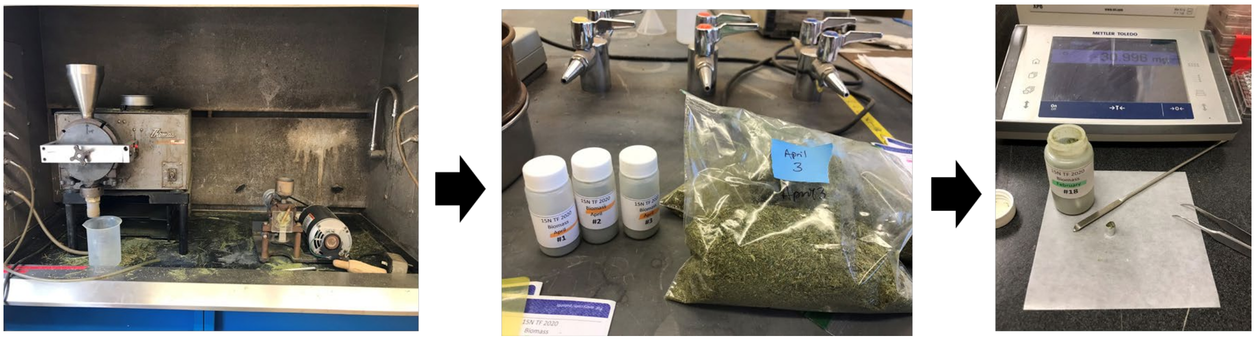

Figure 1. Picture of the process for plant samples, going from two stages of grinding to microbalancing.

SIGNIFICANT ACCOMPLISHMENTS:

- All work for this project was completed by summer 2021 and data analysis commenced. A peer reviewed manuscript was drafted, finished and submitted in fall 2021.
- A student was hired in spring 2021. With this help, we were able to complete all sample preparation for 15N analysis and submit all samples for analysis to UC-Davis Stable Isotope Facility.

Key findings include:

- Across all three sites, there was no effect of fertilizer application timing (early, late, split) on plant N uptake (Figure 2) nor on estimated fertilizer N losses.
- We also saw few differences between sites, although there did not seem to be an effect of soil type or drainage on plant N uptake or N losses
- On average across sites and treatments, 57% of fertilizer applied was recovered in the aboveground biomass at harvest. This number is also called the nitrogen use efficiency (NUE). For most grain systems the NUE is between 30-40%, meaning that in the tall fescue systems studied we saw better use of fertilizer N than average grain systems.
- At harvest 57% of fertilizer N was in the above ground plant tissue, 9% in roots + crown, and 24% remained in the soil (0-45cm = 0-18”). Most of the fertilizer N in the soil at was in the top 15 cm (approx. 6”) (Table 3).

Table 3. Quantity and percent of fertilizer N in each measured component of the system

Component	lbs / ac fertilizer N	% of total fertilizer N
Aboveground biomass (leaves + seeds)	80	57%
Crown + roots	13	9%
Soil 0-6”	22	16%
Soil 6-12”	9	6%
Soil 12-18”	2	2%
Estimated loss (leaching, denitrification primarily)	14	10%

- While 57% of fertilizer N ended up in the above ground biomass at harvest, this was only 31% of the total N in the above ground plant biomass. This means that the soil was able to provide substantial N to the plant, almost 70%.
- Past work has shown that fertilizer N that remains in the soil after harvest can be easily lost in the fall and winter with precipitation that causes surface run-off or leaching. We did not find that to be the case in this study. When we sampled again in January 2021 (year 2), the same amount of fertilizer N was in the system as at harvest (Fig. 2).

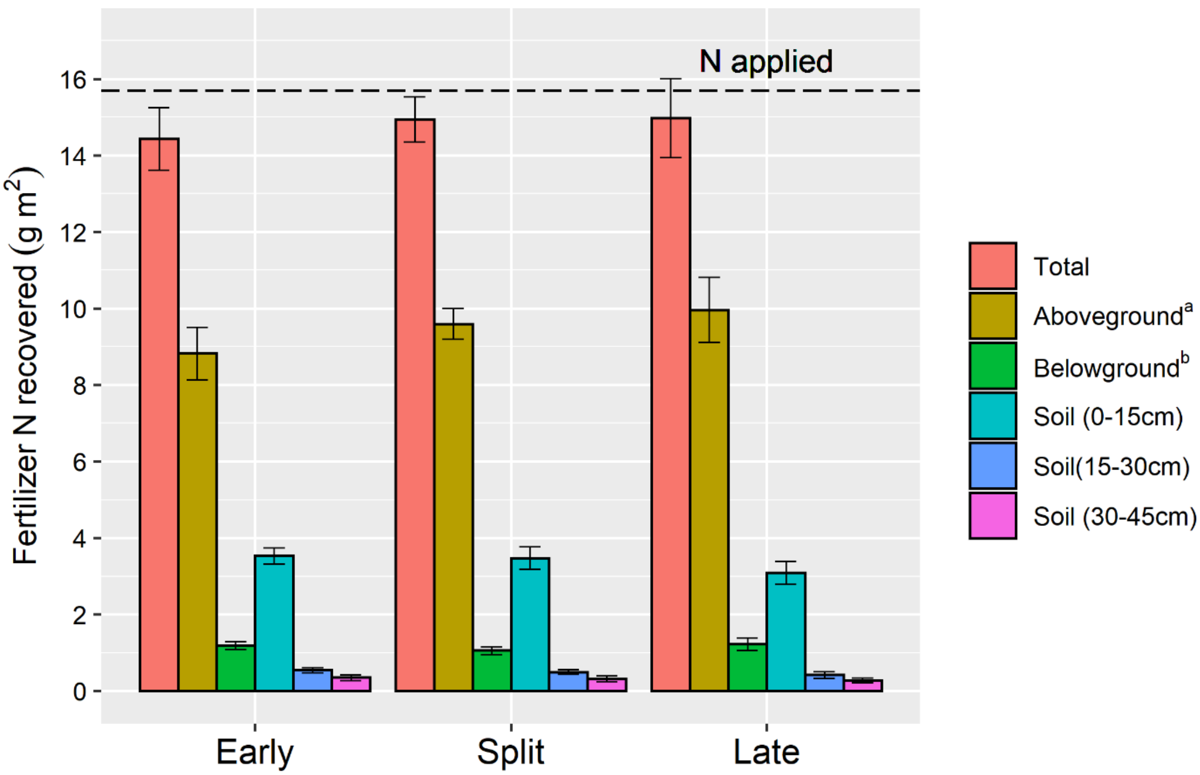

Fig 2. Fertilizer N recovered in the plant-soil system in Year 2 (i.e., the winter following harvest, approximately one year after fertilization). Values were averaged across the three locations as there was not a significant interaction between location and treatment. N fertilizer was applied at a total rate of 15.7 g m^{-2}. There were no significant differences ($p<.05$) between treatments within each component of the plant-soil system. Error bars indicate standard error of means.
[a]Aboveground = removed from the field at harvest + new growth post-harvest
[b]Belowground = roots + crown.

BENEFITS & IMPACT:

- This work was presented at a virtual OSU Extension Seed and Cereal Production Webinar on Jan. 7th 2021 (250 attendees) and final results were presented at in person

OSU Extension Seed and Cereal Production Meetings Jan 5-6th, 2022 (300 attendees over 2 days). Work was well received and timely given the current high price of fertilizer.

- A peer reviewed manuscript on this work was prepared, submitted and just accepted to the journal, *Agronomy*.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM:

The majority of the work outlined in this project was funded at a rate of $25,000 by the Oregon Seed Council and Oregon Tall Fescue Commission ($12,500 each). The funding received from the ARF covered additional costs and analyses that were not included in the primary proposal. The primary proposal only covered costs through harvest of year 1. The original proposal also did not include separate analysis of root + crown at the time of harvest, however in visiting with cooperators they expressed interest in collecting this data, and we agreed it would make a more complete picture so we sought additional funding. This additional ARF funding was critical in following fertilizer fate of residual N one year after application. Additional root + crown fertilizer N analysis funded here, also allowed us to make a much more robust and comprehensive N budget for these systems.

FUTURE FUNDING POSSIBILITIES: