FINAL PROGRESS REPORT

MONTANA FERTILIZER ADVISORY COMMITTEE
FUNDED RESEARCH RESULTS, 2011

1. Project Name

Magnitude of nitrate-nitrogen differences between fall and spring sampling: Effects of previous crop, weather, and soil properties

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3. Objectives

1.) Determine the difference in soil nitrate-N levels between late summer, mid-fall, and early spring sampling
2.) At one location, determine nitrate-N differences on a monthly basis
3.) Develop a simple calculation, or set of tables, based on site conditions that can be used to predict differences in soil test levels between seasons, and therefore allow the crop adviser or producer to adjust fertilizer rates

4. Materials and Methods

This project was conducted at eight soil sampling sites in Montana: Western Triangle (WTARC), Western (WARC), Northwestern (NWARC), Northern (NARC), Southern (SARC), Eastern (EARC), and Central Ag. Research Centers (CARC), plus the Agronomy Post Farm (PF; Fig. 1).

At each site, specific soil sampling locations were identified where the previous crop was 1) a small grain, 2) an oilseed, 3) an annual legume, or 4) fallow. An alternative crop was selected for sites that did not have each of these crops (e.g. no oilseeds were grown at NWARC). For each previous crop, two soil samples were collected that differed in soil texture, and/or, if known, in organic matter at the 0-6 in. and 6-24 in. depths in August to early September (2007-2009), mid-November (2007-2009), and early April (2008-2010). Late summer sampling occurred in September only in 2009 due to a late harvest at many sampling locations. Soil samples were also collected monthly from the late summer to mid fall sampling date at PF. The April soil samples

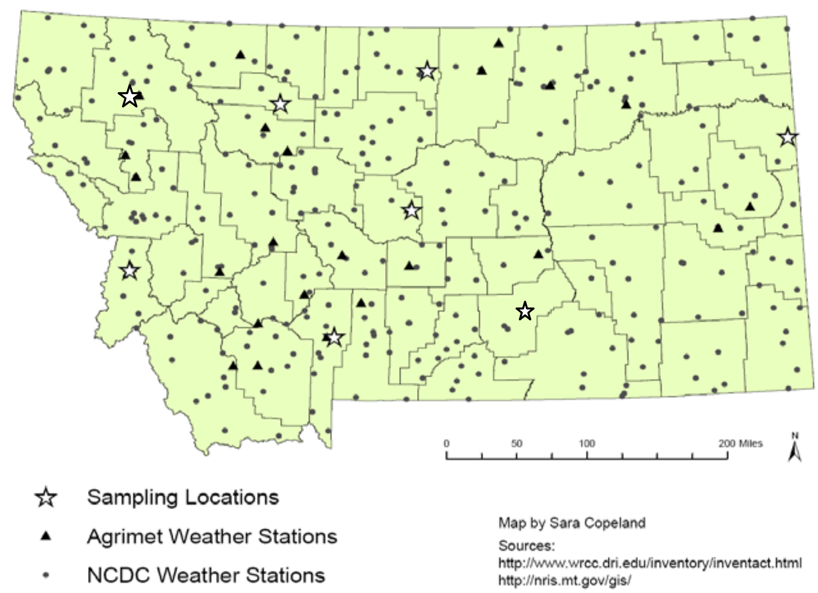

Figure 1. Sampling locations and weather station locations.

were collected one foot from each of the August and November sampling points. A total of 16 soil samples (4 crops x 2 samples/field x 2 depths) at each sampling time were collected, except for the Post Farm where a suitable fallow site was not identified. Sampling times were picked to match approximate times for pre-winter grain sampling, pre-spring grain sampling, and spring seeding times, respectively. The latitude and longitude of each sampling location was recorded using a GPS receiver and/or flags, and each location was well marked for re-location at the subsequent sampling time. Soils at both EARC and CARC were often not able to be sampled to 24 inches, largely due to cobbles. Soil depth was noted in these cases. To assess whether there was spatial variability within a one foot distance, 16 paired samples were collected immediately adjacent to two of the April 2010 sampling locations at each site. These paired samples were located one foot from each other.

All samples were dried at 104º F for one week and shipped to AgSource Harris Laboratories (Lincoln, NE) for analyses. August samples were analyzed for organic matter, pH, nitrate-N, Olsen P, exchangeable K, cation exchange capacity (CEC), soil texture, and soil water content in the upper 6 in., and nitrate-N, soil texture, and soil water content in the 6-24 in. layer. Samples collected in November and April were only analyzed for nitrate-N and soil water content (both depths). Soil water content was determined on sub-samples by drying at 221º F for 24 hours.

The nitrate differences were modeled to produce multiple linear (or non-linear) regressions (using the software "R") with two different data sets: 1) a producer data set that contains data that a producer would have from their own knowledge (previous crop), a typical soil test report (soil depth, Olsen P, exchangeable K, OM, pH, initial nitrate), and a weather station (monthly precipitation and temperature) and 2) a full data set that used the producer data set plus soil texture, CEC, and soil water content. These variables were all included as 'fixed' effects in the modeling effort whereas location and year were considered as 'random' effects. Fixed effects, or variables, can be used to predict nitrate changes, whereas random effects are unknown effects that cannot be used in prediction. Regression models have the form:

Nitrate change = a + b1*x1 + b2*x2 +… bn*xn where a is the intercept, b's are coefficients (or slopes), and x values are the independent variables, such as pH or initial nitrate.

Seven data points were determined to be outliers based on unusually high OM, nitrate levels, or nitrate changes.

5. Project Results and Relevancy to Montana

Results

August to April nitrate-N differences across the three years averaged 18 ± 21 lb/acre (meaning April nitrate-N was 18 lb N/acre more than the previous August nitrate-N). The high standard deviation simply means that there was substantial variability in the data set, and that some soils lost nitrate from August to April. Specifically, NWARC was the only site where nitrate consistently went down over time, likely due to sandy soils. The results suggest that growers who used August or September nitrate-N levels to determine N rates could have fertilized more than they intended by an average of about 18 lb N/acre, but the range of either under or over-fertilization was much higher.

Averaged across site and year, the August to April nitrate differences were 12, 14, 20, and 26 lb N/acre following fallow, small grains, oilseeds, and annual legumes, respectively (Fig 2). Late summer/early fall to April nitrate-N differences were also lower following fallow and harvested wheat than following harvested pea and mustard in a previous Montana study (Miller, unpub. data).

Study year had a significant effect. Averaged across site and crop, August to April nitrate differences were 14, 25, and 16 lb N/ac for 07-08, 08-09, and 09-10, respectively. The middle year was the wettest of the three; when averaged across site, approximately 5.9 inches fell between September and March, compared to about 4.4 inches the other two years. More moisture could either directly increase decomposition rates, or result in more insulating snow cover, thereby indirectly enhancing decomposition by keeping the soil warmer; however, precipitation was not found to significantly affect nitrate-N differences, so other factors, such as growing season climate and yield may have caused the year effect. Location did not have a significant effect on nitrate changes, suggesting soil properties were more important than actual location.

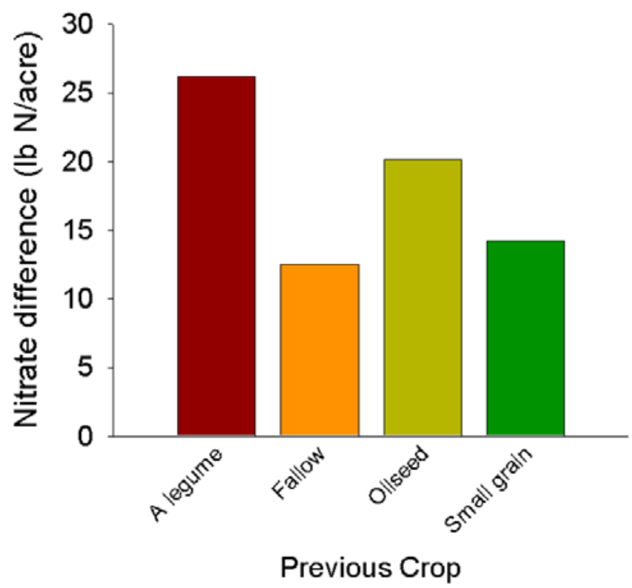

Figure 2. August/Early September to April (April – previous August) nitrate-N changes for each previous crop averaged across 8 sites and 3 years.

The full models performed no better than the producer models (meaning texture, water content, and CEC were not important in explaining nitrate change). The August to April model found that

August nitrate, Olsen P (natural logarithm of Olsen P), and soil depth were highly correlated with nitrate changes (Table 1). Previous crop was somewhat correlated (P=0.08). Higher August nitrate levels were related to lower nitrate changes, likely because more was available to be lost (to leaching, atmospheric losses, or microbial tie-up). Soil depth less than 2 feet also was correlated with lower nitrate changes (by about 10 lb N/ac), either because these sites were more prone to leaching or there was less organic N to become available over a smaller depth. Higher Olsen P resulted in lower nitrate changes, though it's not clear why. Soils with high Olsen P are often coarse textured, because finer textured soils bind P stronger, making it unavailable, and often are high in calcium which also binds P. Coarse textured soils will be more prone to leach nitrate, counteracting gains from N mineralization.

Somewhat surprisingly, OM, pH, precipitation, and temperature were not well correlated with August to April nitrate changes. Notably, increased moisture and temperature are known to increase mineralization. However, increased precipitation would also increase leaching potential or denitrification (conversion of nitrate to nitrogen gas), counteracting nitrate increases from mineralization. Also, soil temperature is highly dependent on both solar radiation and snow cover, neither of which is reflected by air temperature. Although higher OM is generally thought to increase nitrate release, a study in North Dakota found that OM wasn't important in affecting N availability when OM was below 5% (Franzen, unpub data), higher than all but one sample in this study. Plotting predicted vs measured nitrate-N changes shows that the model predictions were often quite poor, especially at very low and high measured nitrate changes. A portion of the poor agreement may have been due to spatial variability; the average absolute difference in nitrate levels of 16 paired samples (2 per site located one foot apart) collected in April 2010 was 14 lb N/acre. This was a larger difference than expected given that nitrate is very soluble and mobile and does explain a portion of the difficulty in modeling the nitrate changes, though is relatively small compared to the range of nitrate changes observed (-60 to +64 lb N/acre).

Table 1. August to April nitrate difference model coefficients for each independent variable, 95% confidence interval (CI) of estimate, and each p-value. A p-value <0.1 is considered significant for this study (bolded); p-values closer to 1 suggest that that variable is not important.

Independent variable	Coefficient estimate	95% Confidence Interval	p-value
Aug nitrate (lb N/ac)	-0.46	-0.59 to -0.33	**<0.0001**
Aug soil depth (if < 2 ft, add this estimate)	-9.08	-15.94 to -2.22	**0.0099**
Previous crop	--	--	**0.0775**
ln (Olsen P; ppm)	-4.59	-9.46 to 0.28	**0.0030**
Year (random effect)	--	--	**0.0010**
Site (random effect)	--	--	1
Sand content (6 to 24 in.; %)	--	--	0.1117
Potassium (0 to 6 in.)	--	--	1
Cation Exchange Capacity (0 to 6 in.)	--	--	1
Soil pH (0 to 6 in.)	--	--	1
Sep to Feb Monthly Air Temp (F)	--	--	1
ln (Total Sep to Feb Precip; in.)	--	--	1
Organic matter content (0 to 6 in.)	--	--	1
Soil water content (6 to 24 in.; %)	--	--	1
Sand content*ln(Total Precip)	--	--	1
Aug nitrate*ln(Total Precip)	--	--	1

November to April nitrate changes averaged 5 lb N/ac over the three year study, demonstrating that the majority of the August to April nitrate change occurred from August to November, when soils were warmer and residue was 'fresher'. Averaged across site and year, nitrate-N changes were -3, 2, 8, and 10 following fallow, small grains, annual legume, and oilseed, respectively (Fig. 4).

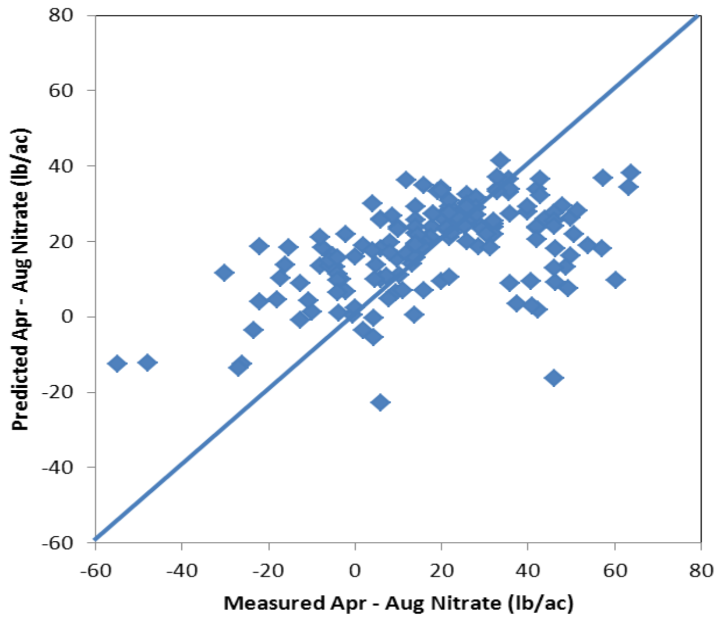

Figure 3. Predicted vs measured April – previous August nitrate-N levels. Also shown is a 1:1 line.

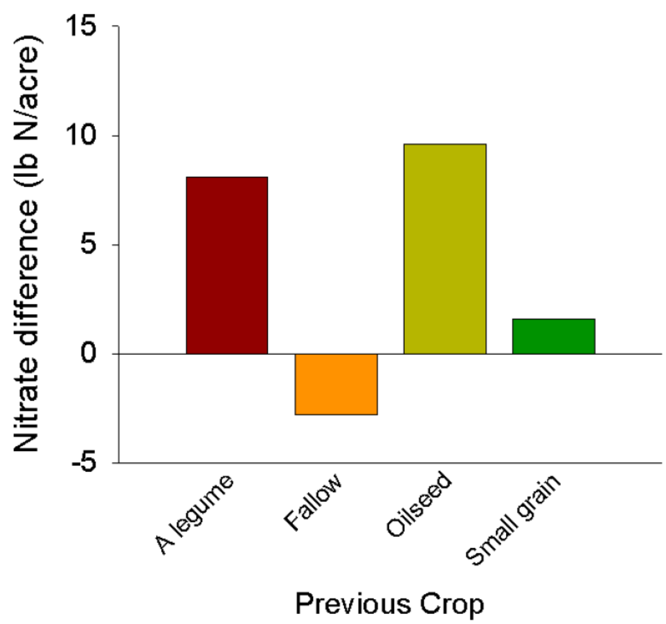

Figure 4. November to April (April – previous November) nitrate-N changes for each previous crop averaged across 8 sites and 3 years.

The producer and full models were again identical, meaning adding additional independent variables did not improve the producer model. The models found that November nitrate, depth, August to April precipitation, and pH were significantly related to nitrate change. Nitrate amounts and depth were negatively and positively related to nitrate changes, though the November nitrate effect was non-linear, unlike in the August model where it was linear. Soil pH was positively related ($P<0.01$) to nitrate change, meaning higher soil pH levels increased the amount of nitrate change, again likely because higher pH soils are apt to contain more clay and/or receive less precipitation and are less prone to leach nitrate. Precipitation was negatively related to nitrate change, unlike in the August model where it did not affect nitrate change. Increased precipitation is known to increase leaching and mineralization, yet after mid-November, mineralization rates are likely more limited by soil temperature than moisture. There was also a year effect ($P = 0.004$). Unlike in the August to April model, there was not a significant crop treatment effect ($P = 0.19$), possibly because easily degraded residues would have already mineralized in the August to November period. The November to April model performed somewhat better than the August to April model, with more points on a predicted vs measured graph closer to the 1:1 line (data not shown). Unfortunately, the usefulness of the November to April model is less, meaning there's less reason for a crop adviser or producer to use this model if sampling occurs in November (or later), because average nitrate changes were much smaller.

The models were unfortunately not accurate enough to have enough confidence in releasing them for predictive purposes. However, the highly significant correlations between nitrate change and both initial nitrate level and soil depth (negative relationships) in all of the models tells us that high fall nitrate levels and low soil depths have the best chance of resulting in nitrate losses. Low nitrate levels following broadleaves have the best chance of resulting in high nitrate gains.

Several recommendations will come out of this work. First, changes between sites and years are large enough that sampling late fall or later is recommended to best capture growing season N availability. Secondly, previous crop does matter with generally higher nitrate changes following broadleaves than following cereals or fallow. Thirdly, if fall nitrate levels are very high and soil depth is less than 2 feet, a second sampling in spring is recommended because there is a higher likelihood of overwinter nitrate losses. Recommendations 1 and 3 will be most problematic for winter wheat growers who apply their N at or near the time of seeding.

Relevance

A substantial number of soil samples are collected in late summer to late fall in Montana, yet laboratories and crop advisers generally do not adjust N recommendations between fall and spring sampling. Based on three years of data, August to April differences in soil nitrate-N levels ranged from about -60 to 60 lb N/ac. The large range suggests that some producers should likely be adjusting their rates, while others may not need to. For producers who adjust for N differences, there is relatively little data available to help make these adjustments. This study has provided information to producers to help them determine optimum soil sampling times, and determine when they should resample.

6. Termination Date: June 30, 2011

Acknowledgments

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