Soil-Test Biological Activity

Relevance and Guidance for Nitrogen Management in Stockpiled Tall Fescue

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The nitrogen (N) dilemma

Nitrogen (N) is considered the most limiting nutrient for grass pastures. Without sufficient N, yield potential suffers. However, too much N can unnecessarily raise costs and reduce profit, as well as become a pollutant to the environment. At either extreme, farmers lose out on economic opportunities and may even lose money.

How are N management decisions made for forages?

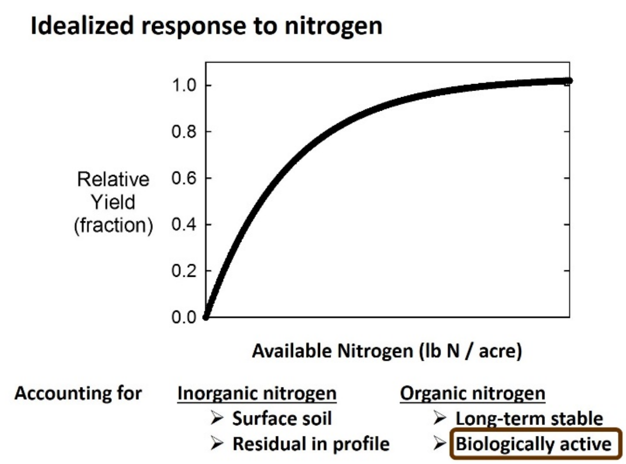
Recommendations vary somewhat by state, but generally are based on research experiments with N uptake potential and average yield response curves to applied N. These experiments follow some basic fundamentals. Reasonably high protein concentration of 15-20% for conserved forages can be expected. This translates to 2.4-3.2% N. Assuming 3% N is a reasonable target, then 60 lb N would be needed for every ton of forage produced. If the goal is to produce 4 ton/acre/year, then 240 lb N/acre would be recommended in split applications. This logic assumes that soil doesn't contribute N, but in fact it does.

How much N is mineralized from organic matter?

Knowing the potential of soil to mineralize N from organic matter would be a step in the right direction to improve N fertilizer recommendations. Traditionally, estimating this pool of mineralizable N was tediously accomplished with incubation of soil under ideal temperature and moisture conditions in the laboratory. A result might be expected within a couple of months to almost a year. New research has shown that this pool of mineralizable N can be accurately predicted within a week of sampling soil from the field.

Plant-available N

Yield of forage grasses is a non-linear function of the amount of N available to that crop. Sources of available N are from inorganic N [i.e. nitrate (NO_3^-) or ammonium (NH_4^+)] and organic N (i.e. N bound to organic matter through chemical bonds). Inorganic N of surface soil (e.g. 0-4" depth) is easily measured through traditional soil testing.



Organic N can now be estimated with soil-test biological activity, which is primarily associated with decomposition of relatively recent organic matter inputs. Biologically active organic matter comes from ungrazed plant residues, animal manures, and roots exploring the surface soil.

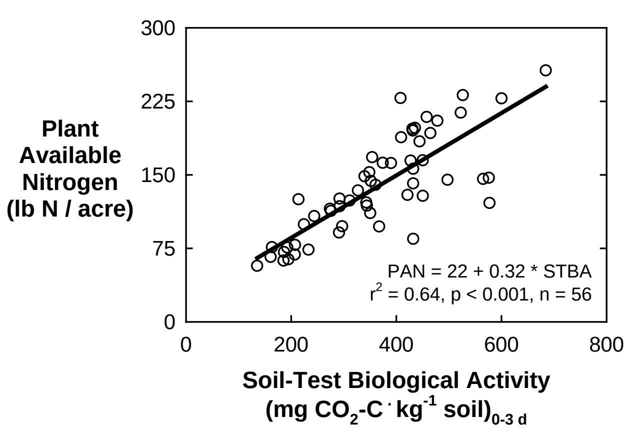
What is soil-test biological activity?

Soil-test biological activity is a short-term test of soils' ability to decompose recent organic matter inputs. It is estimated from capturing carbon dioxide (CO_2) from a sample during a 3-day period. Soil is first dried and sieved so that a representative and standardized condition can be given to all samples tested. The flush of CO_2 that is captured during the first 3 days of incubation relates to soil microbial biomass and to recent organic matter resources present within a soil.

How is soil-test biological activity related to N availability?

Soil is living! Just like carbon (C) is a part of all living things, so too is N. If enough C accumulates, soil organisms will cycle sufficient N from decaying organic materials into plant-available form. Soil is healthy when microorganisms contained within it are working and not exhausted from lack of food – soil needs continual C inputs to be healthy!

Biologically active soil has high N mineralization, i.e. the conversion of organic matter into inorganic N. We can predict the ability of soil to supply N to a crop by determining soil-test biological activity.



Are some soil types relevant and others not?

Soil texture is often a key consideration when making nutrient recommendations. Research has shown that clayey soils are more likely to contain greater soil N mineralization than sandy soils. However, the predictive relationship between soil-test biological activity and soil N availability is not altered by soil texture. This means that soil-test biological activity can be measured equally well in a range of soil textures.

How do I get greater soil-test biological activity?

Grazing practices that follow soil health principles will lead to greater soil-test biological activity over time. Several years of some practices will be needed to change soil to a more healthy state. If you haven't started, the best time is now! Soil health principles include: (1) minimize soil disturbance, (2) keep soil covered, (3) maximize living roots, and (4) energize with diversity. Leaving sufficient residual forage mass and applying organic amendments to pastures are beneficial to soil health.

Could I save money on fertilizer when stockpiling tall fescue?

If soil health on a pasture were excellent with soil-test biological activity $\geq$400 mg/kg/3d, biological cycling of N contained within organic matter could supply enough N to fall-stockpiled tall fescue to produce 4,000 lb forage/acre with crude protein concentration of 18% - using no additional N! The cost savings of not applying the traditionally recommended 80-120 lb N/acre would be \$40-60/acre if cost of N fertilizer were \$0.50/lb N. Nitrogen already on the farm can be used before having to buy more!

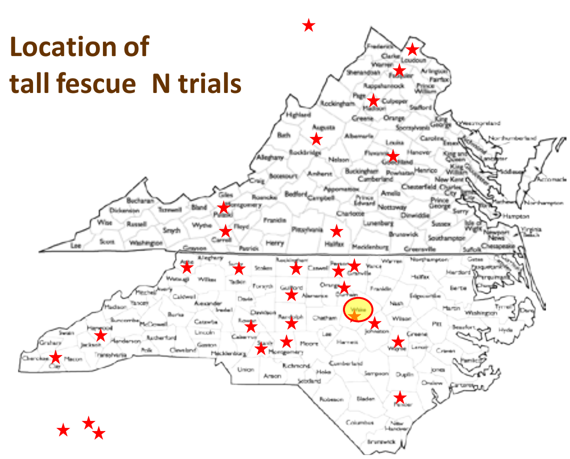
Show me the data...

During the fall seasons of 2015 and 2016, tall fescue yield response trials to applied N were conducted on 57 fields. ***<u>The hypothesis</u>*** was that if N were limiting, then applied N would result in a large increase in forage yield. Alternatively, if N were not limiting, then applied N would not affect yield. Soil-test biological activity (and other indicators of N availability) were measured on each field to indicate inherent N supply from soil, as influenced by historical management of the field. ***<u>The results</u>*** are shown below when field sites were sorted by similar soil-test biological activity.

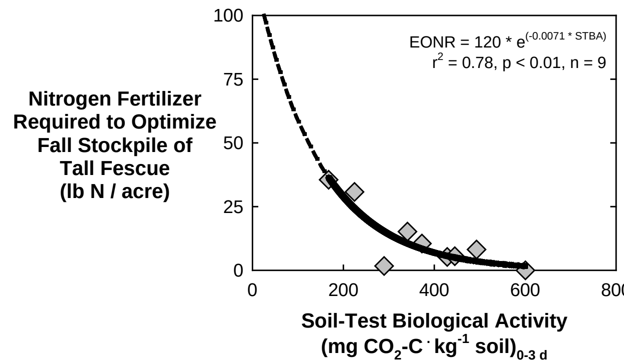
STBA	Sites	PAN	RY	Y_0	EONR
101-200	5	67	0.67	771	41
201-300	10	100	0.84	988	25
301-400	9	136	0.78	1221	17
401-500	15	175	0.81	779	11
>500	6	188	0.92	1269	0

STBA = Soil-test biological activity (mg C/kg/3 d)
Sites = Number of field tests (-12 due to drought)
PAN = Plant-available N from organic and inorganic sources (lb N/a)
RY = Relative yield (without N/with N)
Y_0 = Forage yield (lb/acre) >4" height without N
EONR = Economically optimum N rate (lb/acre) per ton of forage

<u>Sites were distributed</u> throughout NC and VA, as well as a few sites in GA and WV.



<u>Viewed in another way</u>, only soils that had low soil-test biological activity behaved starved for N like the traditional model requiring 40-60 lb N/ton of forage. Soils with increasingly greater soil-test biological activity had N fertilizer requirements that approached zero.



Summary

The greater the supply of soil mineralizable N, the lower the forage yield response to N application. Supply of N in the surface 4" of soil was only partially derived from residual inorganic N and most dominantly from mineralization of biologically active organic matter. Soil N supply was positively associated with relative forage yield without N fertilizer as compared with non-limiting N supply.

As a rapid, reliable, and robust surrogate of soil N supply, soil-test biological activity from the flush of CO_2 effectively indicated (1) relative forage yield response to N fertilizer input and (2) economically optimum N fertilizer requirement. Additional field studies should be conducted on fields with very low soil-test biological activity to validate this approach. This field calibration set with a soil biological indicator of N availability will be an important step towards more efficient natural resource utilization in agricultural landscapes.

Full research paper can be found in *Agronomy Journal* (2018) doi:10.2134/agronj2018.03.0146

Practical guidance for soil-test biological activity sampling

Which fields?

Many fields are appropriate – continuously or rotationally stocked, dryland or irrigated, lowland or upland, and most any soil texture. Cool-season stockpile is the condition that has been tested, but the concept could work in other pasture management scenarios also. Further data collection would be needed to develop calibrations.

When to sample?

For fall stockpiling, sample soil in August toward the end of summer and just prior to fall growth conditions. All N applications after sampling should be accounted in the total N recommendation package going forward, but manure, fertilizer, and legume prior to sampling should be considered embedded in the soil-test biological activity estimate of N availability. Management details should be recorded, if at all possible.

How to sample?

Soil depth matters, so only the 0-4" sampling depth should be collected. A preferable sampling device is a 1" or greater diameter core. Surface residue should be pushed aside prior to coring, but don't remove any mineral soil. Well-decomposed surface litter should be considered a part of the soil. Particles greater than the size of your fingernail can be considered surface residue and should not be part of the sample. Multiple cores should be composited to represent a field. A zig-zag pattern of ~20 cores across a field may be appropriate. Composite up to a pound of soil in a bucket. Transfer soil to a labeled sampling box, paper bag, or plastic bag.

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How to handle soil samples?

Multiple samples collected during the day should be protected from sunlight exposure to avoid overheating. On the day of sample collection, soils should be dried at 60 to 90 °F. Protect samples from excessive dust and contamination from animals. Ideally, samples will be transferred to a paper plate to allow the sample to dry fast with the aid of a fan blowing over samples (up to a day or two). There is no need to break apart soil clods. Once samples are reasonably dry, transfer soil into labeled cardboard box, paper bag, or plastic bag. Ship samples to analytical laboratory in small box.

In the laboratory

Unpack and transfer labeled information to a spreadsheet. Samples in cardboard boxes or paper bags should be placed in forced-air oven at 55 °C overnight to ensure complete dryness of the sample. Samples in plastic bags must be transferred to a paper bag or wide open-top container to dry completely. After dried, soil should be hand-sieved to <4.75 mm or rolled to <2 mm to obtain homogenous sample for subsampling.

Soil incubation

Wet soil to 50% water-filled pore space and incubate at 25 ± 0.5 °C for 3 days. Determine CO_2-C evolved according to standard methods, which can be found at:

1. Franzluebbers (2016) Agricultural and Environmental Letters 1:150009, https://dl.sciencesocieties.org/publications/ael
2. https://www.wardlab.com/haney-info.php
3. https://soilhealth.cals.cornell.edu/training-manual/
4. https://solvita.com/co2-burst/