Soil-Test Biological Activity:

Nitrogen and Stockpiled Fescue

2020-02

Summary of manuscripts in Agronomy Journal

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Core Ideas

- Soil-test biological activity was validated as a good indicator of soil N availability
- Cost-to-value threshold should be considered for N recommendations
- Nitrogen was recycled in pastures through mineralization of organic matter
- Stockpiled forage mass did not respond to P fertilizer application at any location
- Nitrogen fertilization based on soil-test biological activity is a new paradigm

What's the Need?

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 economic opportunities.

Soil N mineralization has not been easily predicted in the past. However, recent research has shown that a simple, rapid, and reliable estimate of soil N mineralization can be obtained from soil-test biological activity. Biologically active organic matter is deposited in soil from ungrazed plant residues, animal manures, and roots exploring surface soil.

Could N fertilizer recommendations be more accurate / site-specific if we tested for soil N mineralization or soil-test biological activity?

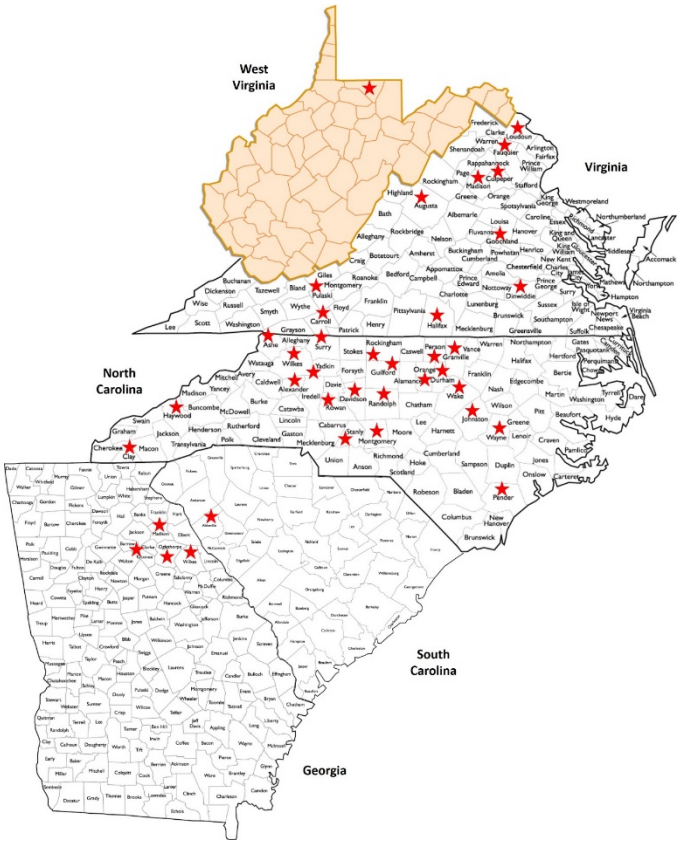
What were the Hypotheses?

1. Greater soil N mineralization and soil-test biological activity in a field would lead to less N fertilizer requirement to achieve economically optimum production.
2. Forage yield would increase with fertilizer P input when soil-test P level was low, but not when soil-test P level was high.

What was Done?

A total of 92 fields in tall fescue pasture were sampled in Aug-Sep 2015 (21 fields), 2016 (35 fields), and 2018 (36 fields) for soil-test biological activity and soil N mineralization. Trials were implemented on each of these fields to test for yield response to additional N and P fertilizer during a fall stockpile period from Sep to Dec-Jan (15 to 20 weeks). Fertilizer N (and fertilizer P in 2018 only) was applied in first week of Sep at 0, 40, 80, and 120 lb N/acre (same rates for P). Forage was harvested from the center of each plot with a rear-bag mower and weighed for yield. Samples were collected for nutritive value analyses. Precipitation in 2015 and 2018 was good, but unusually low in 2016.

Results were peer-reviewed and published in the Sep/Oct 2018 and May/June 2020 issues of *Agronomy Journal*, Vol. 110, Pages 2033-2049 and Vol. 112, Pages 2240-2255. The cover of the May/June 2020 issue (at right) shows Farm Collaborator Steve Sorrells sampling forage.



County location of 92 field trials in this study

What was Found?

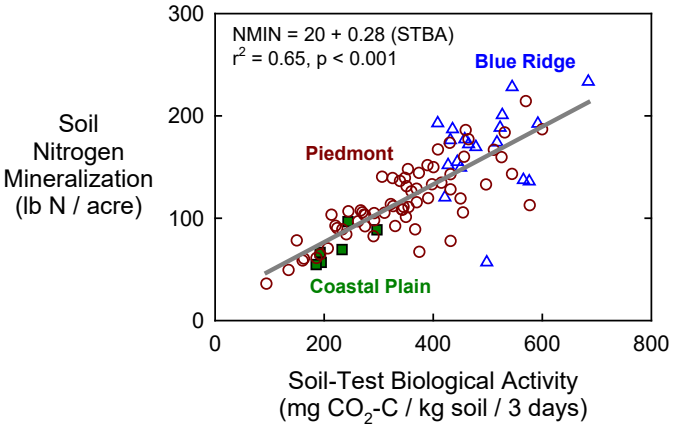
Soil organic matter – Soil properties varied widely due to distribution of test sites in Coastal Plain, Piedmont, and Blue Ridge physiographic regions. Soil organic matter of the 0-4" depth varied from as low as 2.8% to as high as 6.8%, with 4.5% as the mid-point among all sites. These are high soil organic matter levels, mostly because soil had not been disturbed for decades under long-term pastures. Also, grazing systems favor return of dung and uneaten pasture parts to soil.

Statistical distribution of soil properties (0-4" depth) among the 92 field trials was:

Category	BD	STBA	Nitrate-N	P	K
VL	<1.08	<248	<2	<44	<76
L	1.08-1.14	248-343	2-4	44-73	76-102
M	1.14-1.19	343-409	4-6	73-95	102-164
H	1.19-1.28	409-465	6-11	95-161	164-221
VH	>1.28	>465	>11	>161	>221

VL=very low, L=low, M=medium, H=high, VH=very high
BD is bulk density (g/cc), STBA is soil-test biological activity (mg/kg/3d), nitrate-N (mg/kg), and P and K (mg dm^{-3})

Soil nitrogen mineralization – Soil N mineralization varied from a low of 75 lb N/acre to a high of 208 lb N/acre, with 133 lb N/acre as mid-point. Therefore, soil N supply was widely different among sites. Sites in the Blue Ridge had greater soil N mineralization than in the Coastal Plain. Nitrogen mineralization was highly associated with soil-test biological activity (STBA; see figure below). STBA reflects the concentration of active organic matter in soil, including that of the mineralizable N fraction. STBA is much easier to measure, is more consistent, and has shorter analysis time than a direct N mineralization assay. STBA appears to be a good predictor of available N from organic matter.



Association of soil N mineralization with STBA

Forage yield response to P application – Stockpiled tall fescue production was not affected by P fertilizer application in any of the 36 fields evaluated in 2018. Soil-test P varied from 35 to 213 mg dm^{-3} using Mehlich-III extraction. Two-thirds of the sites had soil-test P levels at high or very high categories (i.e. >60 mg dm^{-3}). Lack of yield response was independent of soil-test P. Growing conditions during fall of 2018 were excellent with plenty of precipitation and moderate temperatures.

Forage yield response to N application – Out of 92 field trials over three years, only 13% had yield responses large enough to cover fertilizer N cost. This agro-economic analysis assumed fertilizer N cost of $0.50/lb N and forage as hay equivalent was valued at $200/ton. If hay value were set at $100/ton, then only 5% of the 92 field trials had yield response to fertilizer N large enough to cover the fertilizer cost.

Fertilizer N application was profitable on only a few fields, and those fields were associated with low STBA!

Note: [Cost-to-value threshold of 5 lb forage/lb N was used as marginal return baseline (i.e. $0.50/lb N divided by $0.10/lb forage)]

Forage production during the stockpile period – Fall stockpile production was as low as 1426 lb/acre and as high as 3454 lb/acre, with 2473 lb/acre as mid-point among all sites. From 36 to 50% of this forage was at height of 4" or greater. That meant that 50 to 64% of the forage was nearest to the ground (at 2-4" from ground level).

These production levels suggest that fall stockpiled pasture would support 50 to 100 grazing days per acre. For 25 head of cattle grazing for 60 days with strip grazing, 15 to 30 acres of fall stockpile would be needed.

How Can Lack of Yield Response to Nitrogen be Explained?

We measured soil N mineralization during a 24-day incubation under ideal temperature and moisture conditions in the laboratory. Nitrogen mineralization during this period in the lab represented the equivalent field time of 10 to 18 weeks during the stockpile period (due to temperature and precipitation that were different than in the lab). Soil N mineralization, therefore, was on average greater than the amount of N taken up by stockpiled forage, i.e. from a low of 26 lb N/acre to a high of 74 lb N/acre, with 46 lb N/acre as mid-point. Therefore, soil with high soil-test biological activity under permanent pasture was able to provide sufficient N to stockpiled growth, independent of fertilizer N input. As evidence of the abundant N supply, only 6 to 18% of the N applied in fertilizer was effectively recovered in additional forage yield among the 92 fields.

Historical N fertilizer recommendations of 50 to 100 lb N/acre were reasonable for those fields that had very low soil-test biological activity (i.e. nearly devoid of life in the soil). Soil testing for biological activity could help us determine the level of N needed in other fields.

What is Recommended?

The 92 field trials over three growing seasons on a diversity of farm conditions and locations provided a robust dataset to conclude that significant fall N fertilization on stockpiled tall fescue makes economic sense only under conditions of low soil-test biological activity (STBA).

Funding was provided by USDA-ARS and USDA-NRCS-CIG 69-3A75-14-251

Table 2. Nitrogen fertilizer recommendations for fall stockpiling of tall fescue in North Carolina and surrounding states, based on results of this study.

	Recommendation (lb N/acre)	
STBA Level (mg/kg/3 d)	Low cost of fertilizer	High cost of fertilizer
Very Low, <150	80	40
Low, 150-300	40	20
Medium, 300-450	20	10
High, 450-600	10	5
Very High, >600	5	0