Evaluation of soil tests for predicting nitrogen mineralization in temperate grassland soils

Key messages

- Current N recommendations for Irish grassland systems do not account for N supplied from native soil organic matter (SOM) through the processes of mineralization, but are based on grass growth demand (grazing or cutting), adjusted to account for stocking rate (LU ha^{-1}) and limited by the European Union Nitrites Directive.
- A rapid and reliable soil testing procedure that predicts mineralizable N (MN) is needed for temperate soils as it would help to improve N fertilizer use efficiency (N_fUE), which is important for both agronomic and environmental sustainability.
- The Illinois soil N test (ISNT) was the most effective test for predicting MN across a range of 35 productive mineral grassland soil types, as it explained 69% of MN measured using a standard reference of a 7 day anaerobic incubation (AI-7).
- The ISNT is simple, reliable and robust test suitable as a routine test to predict MN. However, additional studies are required to evaluate the effectiveness of ISNT to predict N supply for grass growth.

Synopsis

Existing measures of N availability test for mineral N levels; however these are unreliable due to the temporal nature of mineral N pools under humid and high rainfall climates. Development of practical applications to measure soil N supply through the mineralization of labile SOM-N has taken place over a number of decades. Biological N tests that include long and short term soil incubations create a soil environment that promotes biological activity and the result is mineralization of liable organic pools over a defined period of time. The 7 day anaerobic incubation (AI-7) is recognised as being a suitable reference indicator of a soil's MN potential (Schomberg et al., 2009). Although these biological incubations are reliable, they are rarely used, as they too time-consuming and impractical for high throughput analysis by soil laboratories. The alternative by many studies has been to develop chemical methods and evaluate their effectiveness to extract the mineralizable N fraction through correlation with standard biological measures. Given the lack of knowledge regarding the effectiveness of many chemical tests in predicting soil N availability in temperate grassland soils, seven reality rapid chemical N tests were evaluated and the relationships between soil N pools measured by these tests and soil properties such as total N, carbon (C) and SOM were explored against MN (i.e. AI-7) for 35 productive mineral grassland soils collected at 10cm depth across the Island of Ireland (Table 1).

A large range in MN (as measured by AI-7) of 92 to 403 mg NH_4-N kg^{-1} was found among the different grassland soil types typical to Ireland. This indicates the need to account for different levels of N supplied through N mineralization within these soils. Therefore, highlighting the potential benefits that could be accrued by adjusting the current "one size fits all" N fertilizer recommendations for these grassland soils.

Table 1. Linear regression equations † of mineralizable N (MN) versus soil N indices across 35 temperate grassland soils.

	Intercept		Slope				
N index‡	**Estimate**	**Standard error**	**Estimate**	**Standard error**	**P >F§**	**RMSE¶**	**r^2**
TN	22.63	28.06	48.39	5.90	<0.0001	45.18	0.67
TC	66.79	24.09	3.66	0.47	<0.0001	46.73	0.65
SOM	29.72	30.99	1.94	0.27	<0.0001	49.2	0.61
Cold_KCL_{NH4}	248.01	20.03	-1.04	4.05	0.7982	78.68	0.00
Cold_KCl_{NO3}	215.50	21.48	1.40	0.84	0.1064	75.67	0.08
Hot_KCl_{NH4}	142.20	33.93	2.00	0.62	0.003	68.81	0.24
Hyd_N	155.78	30.88	1.86	0.60	0.004	69.35	0.22
Acid_Oxd_N	182.59	84.45	0.45	0.61	0.4658	78.12	0.02
UV_260	83.72	36.82	369.34	81.28	<0.0001	61.77	0.39
UV_210	161.46	24.17	469.58	122.02	0.0005	65.44	0.31
Fl_CO2	-169.60	77.03	6.94	1.28	<0.0001	57.32	0.47
ISNT-N	3.38	29.32	0.68	0.08	<0.0001	44.14	0.69

†Equations are of the form Y=intercept +slope(x), where x is the measured N index, and the intercept and slope were estimated by regression

‡TN, total soil nitrogen; TC; total soil carbon; SOM; soil organic matter; Cold_KCl_{NH4}, KCl extractable NH_4-N; Cold_KCl_{NO3}, KCl extractable NO_3+NO_2-N; Hot_KCl_{NH4}, heated KCl extractable NH_4-N; Hyd_N, Hydrolyzable N determined as the difference between hot and cold extractable NH_4-N; $KMnO_4$_oxd_N, potassium permanganate oxidation measured as NH_4-N; UV_260, ultraviolet absorption of KCl extract at 260 nm wavelength; UV_210, ultraviolet absorption of KCl extract at 210 nm wavelength; Fl_CO_2, flush of carbon dioxide in 24 h; ISNT-N, Illinois Soil Nitrogen Test N

Although shown to be highly related with MN (r^2 = 0.61 to 0.67, shown in Table 1), the stable nature of the soil properties total N, C and SOM makes these indices less sensitive to soil management practices such as organic and inorganic fertilizer inputs as well as short-term structural changes caused by soil drying and wetting cycles, typically experienced under temperate climates. These indices may not reflect the potentially labile N supply available for plant uptake in a growing season, but do indicate changes over a longer period of time (i.e. years). In contrast soil mineral N pools measured using KCl extraction did not correlate with MN (r^2<0.08, as shown in Table 1), as this measure of N has been shown to be too transient for estimating plant available N, even under shorter periods (i.e. days) under high rainfall environments, particular to Ireland.

The Illinois N test that determines amino sugars and NH_4-N with direct alkaline hydrolysis in a diffusion method was developed by Khan et al (2001). The tests is based on the identification of the amino sugar fraction of soil organic N to be a labile source of N released by mineralization and shown to be a good predictor of crop response to N fertilizer. Across 35 temperate mineral grassland soils the ISNT was found to be the most effective predictor of MN (r^2 = 0.69, as shown in Table 1).

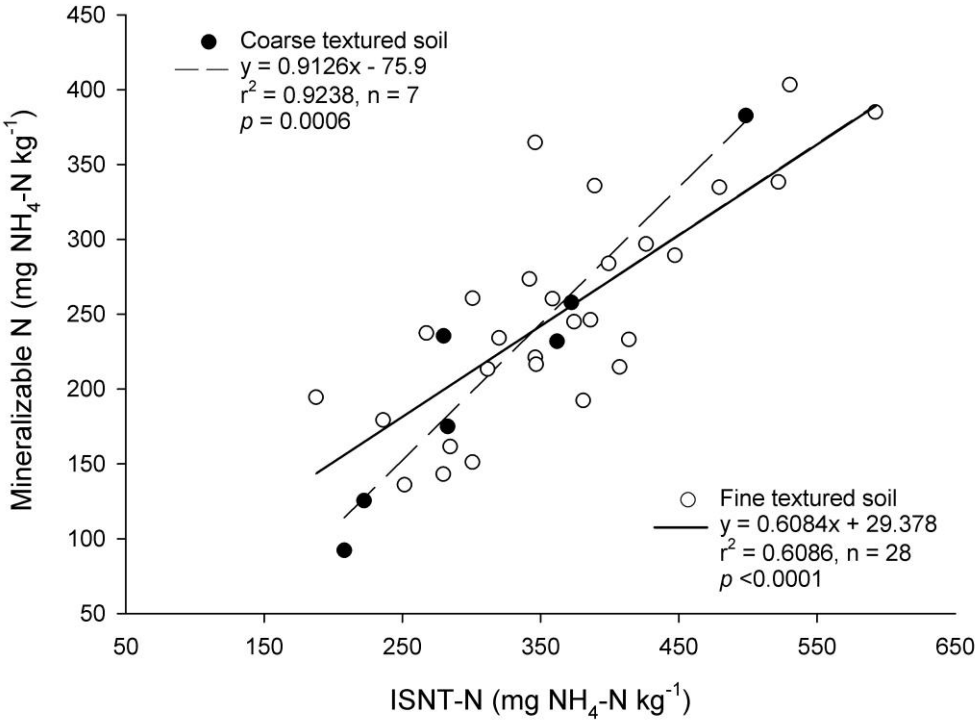

Fig 1. The relationship between mineralizable N measured using a 7 day anaerobic incubation (AI-7) versus the Illinois soil N test (ISNT) across coarse and fine textured soils.

Grouping of soils based on similar textural properties did not give any significant improvement in predicting MN (as shown in Fig 1).

Given the simplicity, reliability, and robustness of the ISNT, it shows the most promise towards routinely predicting MN across various Irish soil types. Further development of the ISNT for this purpose could enable the development of precise N fertilizer recommendations. Hence, improve N_fUE on farms and reduce losses and associated environmental impacts. Continued research is needed to validate the effectiveness of ISNT to predict N supply for grass growth across varying temporal, climatic and management conditions.

This work is published in McDonald et al. (2014a).

References

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