EVALUATION OF SOIL TESTS FOR POTENTIALLY MINERALIZABLE SOIL NITROGEN IN SNAKE RIVER PLAIN SOILS IN IDAHO

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ABSTRACT

Soil testing is a critical component of fertilizer management strategies for ensuring optimal nutrient applications for agricultural crop production while minimizing potentially negative environmental impacts due to excess fertilizer applications. Research to determine accurate soil test methodologies dates back over 150 y; however, a rapid soil test for the determination of potentially mineralizable nitrogen (N) that consistently provides reliable results has alluded researchers. A recent resurgence has occurred focused on methods to determine a rapid soil test to predict potentially mineralizable N. Irrigated field sites in southern Idaho (n = 34) near the Snake River Plain area were selected to represent a range of soil and production characteristics common to the region. Samples were collected from the 0- to 12- and 12- to 24-in depths, which represents the current recommended sampling depths for the majority of agricultural crops grown in the region. A 7-d anaerobic incubation (NMIN) was conducted as the standard to which rapid tests were compared. A multitude of rapid tests were performed (i.e., total C, N, loss on ignition, Walkley-Black, Illinois Soil Nitrogen Test (ISNT), direct steam distillation (DSD), Solvita labile amino nitrogen (SLAN), and CO_2 burst). Each test was conducted on a subsample from each depth at each location and comparisons to NMIN were made using Pearson correlation. While most tests were correlated with the NMIN test, noticeable issues were noted in specific tests (e.g., SLAN test was not sensitive enough as most samples were below the detection limit). Direct steam distillation was most highly correlated at both sampling depths (r =0.767 and r = 0.828 for the 0-12 and 12-24-in depths, respectively). While the DSD test was well correlated with N-min in southern Idaho soils at both sampling depths, the test must be correlated and calibrated with crop response parameters to be useful in Idaho crop production.

INTRODUCTION

Nitrogen (N) is an essential plant nutrient that plays a major role in photosynthesis and thus, is required to maximize yield potential in cropping systems. Despite an understanding of the processes that result in N mineralization in soils, accurately predicting the amount of plant available N during the growing season has proven difficult. Biological methodologies have historically been the most promising, but difficulty arises with implementing these tests in soil testing facilities due to space and labor needs as well as the time to complete analyses (i.e., 7 d or greater) (Bushong et al., 2008). Additionally, crop response is not always well correlated to biological incubation tests.

Recently, researchers have revived the search for a rapid-soil test that can accurately predict N mineralization utilizing a range of procedures. Khan et al. (2001) who introduced the Illinois Soil Nitrogen Test (ISNT) were largely responsible for the resurgence in efforts to develop an accurate rapid-soil test where the ISNT was initially released as a method to determine whether corn would respond to fertilizer N applications in Illinois. However, both positive and negative results, as well as issues with the test, have been noted during research trials (Khan et al., 2001, Barker et al., 2006, Sharifi et al., 2007, McDonald et al., 2014, Osterhaus et al., 2008). Modifications to the ISNT (Lawrence et al., 2012) as well as an alternate test [i.e., direct steam distillation (DSD) that was highly correlated to the ISNT ($r^2 = 0.90$)] that, similar to the ISNT, extracts alkaline hydrolysable N (AHN) (i.e., ammonium N, amino sugars, and some amino acids) under different procedural conditions (Bushong et al., 2008). The DSD soil test has been correlated and calibrated for usage in Arkansas's rice producing soils and now is widely used for determining N recommendations (Roberts et al., 2013). However, rice producing soils are markedly different from upland soils as a function of the flooded soil environment that regulates soil processes reducing aerobic N processes during the season.

Chemical methods to measure N mineralization represent the most rapid procedures that are available at this time; however, recent studies have indicated that a biological method where soil is dried and rewetted and the subsequent CO_2 burst is measured has been proposed as an alternative to chemical methods (Franzluebbers et al., 2000; Haney et al., 2008). Other studies have found lower correlation from the CO_2 burst when compared to NMIN in comparison to other methodologies, including the ISNT (McDonald et al., 2015). Despite several positive initial results (Haney et al., 2001, Haney and Haney, 2010) the applicability of this test warrants further investigation, particularly in the unique soils found in southern Idaho's Snake River Plain. The objective of this research was to evaluate several common soil testing procedures as well as recently introduced tests as compared to NMIN as potential predictors of N mineralization.

METHODS

Soil samples were collected from irrigated production fields near the Snake River Plain region of southern Idaho from the western to eastern areas of the state and represented the majority of scenarios of potential previous crops commonly grown in the region (i.e., alfalfa, barley, corn, dry bean, oats, potato, sugar beet, and wheat). Current fertilizer recommendations vary based on the crop to be grown where a 0 to 12 in sample depth is used for potatoes and a 0 to 24 in depth is used for small grains and sugar beets (Brown, 1996, Moore et al. 2009, Robertson and Stark, 2003, Stark and Westermann, 2003). Soil samples were collected from approximately a 0.25-acre area of each field within a single soil series verified in field using SoilWeb (http://casoilresource.lawr.ucdavis.edu/soilweb/) where four sample cores were taken using a 3-in bucket auger from each depth and composited. After collection, samples were dried at 104 F° crushed and passed through a 2-mm sieve.

Soil test protocols were based on standard procedures of soil testing and analysis (Gavlak, 2005). Soil particle size was measured using the hydrometer method, pH was determined potentiometrically on a 1:1 w/v ratio using DI water, $CaCO_3$ was measured using a pressure calcimeter due to the high pH and known presence of $CaCO_3$ in many soils in the region. Initial soil NH_4-N was determined by 2*M* KCL extraction and spectrophotometric analysis. Table 1 lists initial soil property ranges for the 0- to 12- and 12- to 24-in depths.

Soil Tests/Indices

In the current study, NMIN was used as the standard where a multitude of rapid tests were performed (i.e., total C, N, loss on ignition (LOI), Walkley-Black, ISNT, DSD, Solvita labile amino nitrogen (SLAN), and CO_2 burst) and compared to NMIN. Duplicate samples of each test were performed for each site by depth combination.

The 7-d anaerobic incubations were conducted using 20 g of soil incubated using 50 mL of DI water at 40 C° for 7 d (Waring and Bremner, 1964; Gavlak et al., 2005). Following the 7-d incubation, samples were extracted with 2*M* KCL and analyzed colorimetrically. Initial measured NH_4-N was subtracted from the final NH_4-N concentration (Waring and Bremner, 1964). Total C and N were measured via combustion analysis using a VarioMax CN analyzer (Elementar Americas, Inc. Mt. Laurel, NJ). Soils often exceeded pH 8.0 and had large amount of $CaCO_3$ (Table 1), thus, organic C (OC) was determined via subtraction, (%OC, % = % total C - % inorganic C), and was used in the study (Nelson and Sommers, 1996). Samples were measured for LOI where 10 g of sample was combusted in a muffle furnace at 360 C° (Gavlak, 2005). The Walkley-Black titration method was also conducted on samples based on the reaction with dichromate and sulfuric acid (Nelson and Sommers, 1996). Soils were analyzed using the ISNT where samples were extracted in a modified mason jar treated with 2*M* NaOH and heated on a modified hotplate, samples were collected in H_3BO_3 acid and titrated using 0.01*M* H_2SO_4. Direct steam distillation was conducted on samples where soil was distilled using a steam still. Soil was added to a steam distillation flask and treated with 10*M* NaOH where distillate was collected in H_3BO_3 and extracted using 0.01*M* H_2SO_4. Solvita labile amino nitrogen was measured on samples, in contrast to the other AHN tests, no external heat is used in any form, soil was added to a 30 mL cup and 2*M* NaOH was used to treat the samples, immediately following addition of the NaOH a SLAN paddle (Woods End Laboratories, Mt. Vernon, ME) was placed within the 250mL jar with accompanying rubber seal and immediately sealed where samples were read using the Solvita digital color reader (DCR) after a 24 h incubation at 22 to 25 C°. Carbon dioxide release upon rewetting was measured using Solvita Haney-Brinton test kit for C and N mineralization (Haney et al., 2008). Soil bulk density was estimated on dried and crushed samples based on the volume 40g of soil occupied in the plastic beaker where water was added via a top-down method to approximately achieve field capacity. After the addition of water, the plastic beaker was placed in a 250 mL glass jar with a rubber seal (Woods End Laboratories, Mt Vernon, ME) and incubated at 22 to 25 C° for 24 h. Following the 24 h period samples were removed and paddles read using the DCR.

Statistical Analyses

Individual sample duplicate means were calculated and used for analyses. Pearson correlation coefficients were used to determine the relationships between rapid soil tests compared to the 7-d anaerobic incubation as well as to one another. All tests were conducted in SigmaPlot 13 (SYSTAT, San Jose, CA).

RESULTS AND DISCUSSION

Characteristic of the agricultural production areas of the region, 92% of soils were classified as either silt loam (n=23) or loam (n=8) where one soil was classified as loamy sand, sandy loam, and sand, respectively. Samples were relatively low in organic matter (OM) as quantified by LOI and Walkley-Black tests where the majority of samples ranged from <1 to 2 % OM.

Results from the 0- to 12-in depth indicated all tests were correlated to the NMIN test where the DSD was most highly correlated (r = 0.767) followed by LOI (r = 0.739) and ISNT (r = 0.712 (Table 2). At the 12- to 24-in depth, the results were similar where DSD was the most highly correlated (r = 0.828) followed by LOI (r = 0.761) and the ISNT test (r = 0.712). As noted in Table 2 and 3, the SLAN test, which operates under the same general principles as the DSD and ISNT tests except no external heat is added, resulted in noticeable detection issues as the majority of samples were non-detects, and thus, the SLAN test was excluded from analyses. Issues with the SLAN methodology in the current study are potentially related to the low OM content in the majority of samples analyzed.

Issues with the correlation of AHN tests (i.e., DSD and ISNT) to TN have been noted in previous research. In the current research correlation was measured between DSD and ISNT with respect to TN. However, DSD and ISNT were more strongly correlated to NMIN at both depths, particularly the 12 to 24 in depth where the correlation between the AHN tests and TN decreased. This indicates that the AHN tests are likely more sensitive at measuring readily mineralizable N-compounds, especially as deeper sampling depths are included, as compared to TN for the soils in the study.

In addition to the AHN tests the strong correlation of NMIN with LOI should be investigated in terms of crop response as this test is routinely conducted in the region and used by commercial soil testing labs as an indicator of N mineralization. The CO_2 burst test was correlated where r = 0.566 and r = 0.624 for the 0- to 12- and 12- to 24-in depth, respectively. However, this correlation was lower than other tests and exhibited marked variability indicating other rapid tests studied are potentially better predictors of mineralizable N.

CONCLUSIONS

Research focused on developing an accurate measure of N-mineralization has proven difficult with limited examples of successfully implemented tests for crop production. The current study provides evidence of several promising tests that have the potential to improve estimates of N availability in cropping systems. In particular, continued research on the AHN tests and LOI as predictors of N mineralization may prove useful. However, this research represents the 1st phase of research, which was to determine correlation among soils in a laboratory environment to narrow down the most promising tests for further research in the region. Field trials are currently underway in Idaho to determine if laboratory correlations are applicable in-field and will be correlated to crop response parameters. Thus, any potentially viable soil test to predict N availability must be correlated and calibrated with crop response parameters to be useful in Idaho crop production.

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Table 1. Minimum and maximum values of selected soil physical and chemical properties for soils collected throughout southern Idaho (n=34) from the 0 to 12 and the 12 to 24 in sample depth

Sample Depth	Sand	Silt	Clay	NH_4-N	pH	$CaCO_3$
	---------------------	%-------------------		mg/kg		%
0 – 12 in	12-89*	2-75	7-23	2.6-7.3	7.6-8.8	<0.5-32.8
0 – 24 in	9-87	4-72	8-23	2.7-4.8	7.6-8.3	<0.5-51.4

*Minimum-Maximum

Table 2. Pearson correlation coefficients for soil tests conducted on soils collected throughout southern Idaho (n=34) for the 0- to 12-in sample depth

	TN	OC	LOI	WB	ISNT	DSD	CO_2	SLAN*
NMIN	0.674	0.549	0.739	0.607	0.712	0.767	0.566	-
TN		0.862	0.957	0.947	0.938	0.968	0.244	-
OC			0.808	0.834	0.823	0.817	0.096	-
LOI				0.915	0.924	0.984	0.351	-
WB					0.857	0.917	0.218	-
ISNT						0.944	0.352	-
DSD							0.347	-

*SLAN was excluded from analyses as the majority of samples were below detection limit

Table 3. Pearson correlation coefficients for soil tests conducted on soils collected throughout southern Idaho (n=34) for the 12- to 24-in sample depth

	TN	OC	LOI	WB	ISNT	DSD	CO_2	SLAN*
NMIN	0.525	0.325	0.761	0.596	0.734	0.828	0.624	-
TN		0.792	0.567	0.235	0.508	0.612	0.213	-
OC			0.318	0.125	0.327	0.354	0.088	-
LOI				0.695	0.746	0.902	0.56	-
WB					0.468	0.568	0.331	-
ISNT						0.816	0.695	-
DSD							0.584	-

*SLAN was excluded from analyses as the majority of samples were below detection limit