EFFECT OF TILLAGE, ROTATION (MAIZE AND SOYBEAN), AND NITROGEN RATE IN A LONG TERM STUDY ON SOLVITA, WATER EXTRACT, H3A EXTRACT VALUES

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Abstract

A long term rainfed tillage/rotation/N rate study was established in 1985 on a mostly Coleridge silty clay loam (fine-loamy, mixed, superactive, mesic Cumulic Haplustoll). The study is a factorial of plow, disk, and no-till under continuous corn (Zea mays) and corn following soybeans (Glycine Max) with five nitrogen rates (0, 40, 80, 120, 160 kg ha^{-1}). Soil samples were taken from all rotation/tillage combinations and three N rates in the fall of 2013 to 0.20 m (8 in). They were analyzed using the Haney H3A extract, Solvita CO_2 24hr evolution, Soil Health Calculation (SHC) and conventional nitrate soil tests at Ward Laboratory. The results indicate that the soil nitrate tests picked up more differences due to tillage and rotation than the Solvita and SHC. The Solvita and the SHC results picked up more differences due to nitrogen application and its interaction with tillage and rotation. This paper is partial and preliminary since all the data has not been analyzed.

Introduction

The Solvita and Haney/Soil Health Tests are emerging methods of soil testing which integrates chemical and biological soil test data to assess the health of the soil (Haney et al., 2006; Haney et al., 2008). These tests may complement or supplement traditional soil testing procedures. For the purpose of this paper we will call these tests biological soil tests. The Solvita test quantifies the amount of respired CO_2 after rewetting a dried soil sample over a 24hr period and has been proposed to be used to quantify microbial activity and mineralizable N and P. The Haney or Soil Health Test uses water and the extractant, H3A (which was designed to mimic plant root exudates) plant available nutrients and soil health. This extractant is a combination of lithium citrate, citric acid, malic acid and oxalic acid. The Soil Health Calculation (SHC) uses values from both of these tests to provide a score indicating the overall health of the soil (a "good" score is above 7). The equation used to calculate the SHC is as follows: SHC= ((Solvita CO_2 / Organic C:N) + (Water Extracted Organic C / 100) + Water Extracted Organic N /10)). The details of each of these tests can be found at: http://solvita.com/pdf-files/Haney-Brinton_paper2_SPA.pdf. In addition the laboratory that conducted these analysis (Ward Laboratories, Kearney, NE) has more information about these tests on its website (http://www.wardlab.com/haney/haney_info.aspx; http://www.wardlab.com/solvita/solvita_info.aspx).

The H3-A extract is well correlated with several of the established extractants (Haney et al., 2006). Our interest is not in the correlation with other extractants, it is with what these tests can add to our understanding of the soils, and whether we can quantify the effect of management. The purpose of this project is to compare the results of conventional chemical soil tests with the biological tests to determine what additional understanding about the effect of our long-term

field experimental treatments of tillage, crop rotation, and nitrogen rates can be gained. This is a preliminary analysis and we will focus on several soil nitrogen tests, the Solvita CO_2, and the SHC.

Methods

The data for this study were collected from a long-term field experiment in eastern Nebraska. The study was established in 1985 on a mostly Coleridge silty clay loam (fine-loamy, mixed, superactive, mesic Cumulic Haplustoll). The general fertility is more than adequate for most nutrients (organic matter 4.0 %, K, 332 ppm, Mehlich 3 P 58 ppm, CEC 25.5 me/100g, Zn 1.4 ppm), but the pH is slightly acid (5.8) with a buffer pH of 6.3. The experimental design and treatment arrangement is a split-split plot design with four replications under rain fed conditions. Whole plot treatments consisted of a) tillage treatment as main plot with 3 levels: moldboard plow (followed by a disk), disk tillage and no-till; the first split was b) crop rotation: continuous corn [*Zea mays L.*](CC) and corn-soybean [*Glycine max (L)* Merr.] rotation (CS) with each phase of the CS in each year; and the sub-sub plots: c) N fertilizer rates as; 0 kg N ha^{-1}, 80 kg N ha^{-1}, and 160 kg N ha^{-1}. Each N treatment was 20 ft. wide x 35 long and contained 8 2.5 ft. rows. These data were a subset of treatments from a larger experiment which had 5 N levels. Samples were collected in the fall of 2013 after harvest. Nitrogen fertilization was only applied to corn as ammonium nitrate and was broadcasted usually before tillage took place in the spring. Corn seeding rates were 63,500 plants ha^{-1}. Phosphorus fertilizer was applied when necessary based on soil test using the University of Nebraska interpretations. Corn grain yields were quantified for each treatment by harvesting with a plot combined designed for small areas. In the fall of 2013, each experimental unit was sampled at a depth of 0.20 m with a hand probe (5 cores/sample) and sent for analysis at Ward Laboratories (Kearney, NE). In fall, 2013 the complete soil test analysis was conducted using standard analysis methods. In the spring, 2014, the Haney and Solvita tests were conducted from the fall samples.

Statistical Analysis

Data obtained from the traditional and Haney soil tests and yield were analyzed statistically with PROC GLM module in SAS (SAS Institute, 2014) with a split-split-plot experimental design. The TEST statement was used to test the significance of the whole plots with 'error a' (Replication x Tillage) and the sub-plots crop rotation and the interaction of crop rotation and tillage with 'error b' (Replication x Tillage x Rotation). LSMEANS are reported and LSDs at 0.05 are reported for main effects. The LSDs for Tillage and Rotation main effects were calculated using error a and b, respectively.

Results and Discussion

Since our interest is in what increased knowledge we can gain from using the Haney and Solvita tests we will concentrate our discussion on the differences with the traditional analysis, and not on the agronomic effects of the treatments. The ANOVA for the yield results from the last 10 years and for 2013 are presented to give context to how this site is responding to the treatments (Table 1). Over the long term, it is quite clear that there are consistent rotation (CS > CC) and nitrogen effects on grain yield. Tillage effects are more variable with there being only 3 years in the last 10 with significant yield differences, Both 2012 and 2013 were significant, with the drought year of 2012 yielding 9, 48, and 68 bu/acre ($LSD_{0.05}$ 7 bu/acre) for plow, disk, no-till,

respectively, compared to 2013 yielding 168, 173, 161 bu/acre^{-1} ($LSD_{0.05}$ 8 bu/ac), respectively. In 2012 precipitation was 18 inches and in 2013 it was 27, with the long term average 29 in/calendar year.

Comparing the results of the analysis of variance for the nitrogen indicators and starting at the top of Table 1 shows that the nitrogen soil tests (Fall conventional (nitrate nitrogen), Haney traditional (nitrate nitrogen converted to lbs N/acre), and Haney N availability (combination of nitrates, ammonium and N release) were similar and all picked up differences, but the Solvita and Soil Health Calculation could not delineate between tillage treatments. This could mean that 25 plus years of plow vs no-till made no difference in soil 'health' or that the test is not picking up differences. The Fall conventional and Haney traditional both measure the same parameter, soil nitrate-N. The Fall conventional was conducted in the fall, and is reported in ppm. The ppm do not convert to the Haney traditional lbs/acre. However, the ANOVA results are similar, but not exact.

Table 1. Analysis of variance for long term yields, 2013 yields, fall soil nitrates, Haney traditional N, Haney available N, Solvita CO_2 evolution, and Soil Health Calculation.

ANOVA			Nitrogen				
Main Effect and Interactions	Average corn grain yield 2004-2013[1]	2013 Grain Yield[2]	Fall conventional NO_3-N[3]	Haney Traditional N[4]	Haney N in lbs N/acre available[5]	Solvita CO_2	Soil Health Calculation
		Significant F tests, NS > 0.20; + >0.10; * 0.05; ** > 0.01; ***> 0.001; ****<0.001					
Tillage	NS	**	*	*	*	NS	NS
Rotation	****	****	+	*	*	*	+
Rotation x Tillage	NS	+	*	+	NS	NS	NS
Nitrogen Rate (N Rate)	****	****	****	****	****	****	****
Tillage x N Rate	+	*	NS	NS	NS	****	****
Rotation x N Rate	NS	NS	**	NS	*	***	**
Rotation x Tillage x N Rate	NS	*	+	NS	NS	***	***
CV (%)	9.7	7.1	25	31	15	12	8.3

[1]F values average of annual ANOVA. [2]2013 was year after a severe drought in 2012.
[3]Analysis using traditional KCL extractant, reported in ppm.
[4]Analysis conducted as part of the Haney package, ANOVA results should be similar to the Fall conventional test, except reported as lbs N/acre. [5]Calculated from nitrates, ammonium, and nitrogen release.

Yields picked up rotation effects (Prob.>F were <0.001 in all years) more than any of the soil and biological tests (Prob.> F ranged from 0.05 to 0.20) although all of the tests picked up

differences to some degree. The 2013 yield increase from CS compared to CC was 30 bu/acre and the long term difference was 20 bu/acre. The Solvita CO_2 test for CC was 77 ppm and for CS was 83, the Soil Health Calculations were both 11. One might expect that 25 years of CC would affect microbial activity relative to CS. This was only marginally true for the Soil Health Calculation.

The Solvita and the Soil Health Calculations picked up the effect of nitrogen and the interactions of nitrogen, tillage and rotation with much lower F statistics than yield or the soil nitrogen variables (Table 1). As an example of the interactions, the means for the tillage x nitrogen rate treatments are presented in Table 2. The contrast between the soil nitrogen parameters and the biological ones is clear. As N is increased, the soil nitrates increased for the traditional nitrate measurements and the Haney N availability. However, for the Solvita and the Soil Health Calculation the trend is downward for the high nitrogen treatment. This is consistent over tillage treatments for the CO_2 evolution, but more pronounced with the disk and no-till treatments for the Soil Health Calculation. The CO_2 evolution differences are more pronounced for the disk and no-till compared to the plow. The percent difference between the ppm CO_2 evolved at the 0 and 160 N kg ha^{-1} rate was 90, 80, and 60% for plow, disk, and no-till, respectively. In addition, the CO_2 evolution was higher at 0 and 80 N rate under no-till than any disk or plow treatment, and lower than any plow or disk treatment for the 160 N rate.

Summary

Comparison of the traditional N tests and the Solvita and Haney tests indicated areas where there was similar sensitivity and areas where the Solvita CO_2 and the Soil Health Calculation might be more sensitive to soil processes. Of most interest was the interactions between nitrogen, tillage and rotation. The effect of higher nitrogen rates decreased CO_2 evolution, especially for the no-till. The Soil Health Calculation indicated that all tillage and nitrogen rates were generally high, the high N rate decreased the Soil Health Calculation for the disk and no-till treatments. The analysis presented in this paper is preliminary and there are other parameters in this suite of tests that need to be analyzed before more conclusions can be drawn. Similar analysis for many other studies that have been conducted for several years and have established different management practices are needed to establish where these tests can add to our understanding of the effect of management on soil processes.

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Table 2. Effect of tillage, nitrogen rate and the interaction on grain yield, fall soil nitrates, Haney traditional nitrates, Haney nitrogen availability, Solvita CO_2, and the Soil Health Calculation.

Tillage	Nitrogen rate	Average corn grain yield 2004-2013[1]	2013 Grain Yield[2]	Fall conven-tional NO_3-N[3]	Haney Tradition al N[4]	Haney N in lbs N/acre available[5]	Solvita CO_2	Soil Health Calculat ion
	kg ha^{-1}	bu/ac		ppm N	lbs/ac	lbs/ac	ppm	index
Plow	0	107	163	5	9	49	80	10.6
Plow	80	136	175	18	27	72	78	11.8
Plow	160	147	165	42	65	114	72	11.0
Plow mean		130	168	22	34	78	77	11.1
Disk	0	108	159	7	8	49	85	11.3
Disk	80	144	177	22	36	85	83	12.2
Disk	160	156	182	42	74	120	69	9.6
Disk mean		136	173	24	39	85	79	11.0
No-till	0	108	146	6	7	50	102	12.0
No-till	80	150	167	25	39	94	90	12.8
No-till	160	157	169	46	80	126	61	8.8
No-till mean		138	161	25	42	90	85	11.2
N rate means								
	0	108	156	6	8	49	89	11.3
	80	143	173	22	34	84	83	12.3
	160	154	172	43	73	120	67	9.8
LSD 0.05								
	Tillage	--	6	3	8	10	10	1.5
	N rate	--	7	4	7	7	6	0.5

[1]No F values since means are an average of annual ANOVA.

[2]2013 was an odd year after a severe drought in 2012.

[3]Analysis using traditional KCL extractant, reported in ppm.

[4]Analysis conducted as part of the Haney package, ANOVA results should be similar to the Fall Conventional test, except reported as lbs N/acre.

[5]Calculated from nitrates, ammonium, and nitrogen release.

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