Solvita and Other Mineralizable Nitrogen Tests as Indicators of N Response in Minnesota Soils

FINAL REPORT

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1) GOALS AND OBJECTIVES OBTAINED

There is rapidly growing interest in the possibility of a fast, easy tool like the Solvita test to improve N recommendations, but little is known about how well the results can be calibrated for and applied to Minnesota conditions. The objectives of this study were to: 1) compare Solvita test results with standard laboratory aerobic incubation results for potentially mineralizable nitrogen (PMN), and with other potential measures of N availability, including extractable nitrate-N, organic matter content, N mineralized after 32 and 64 days laboratory incubation and permanganate-oxidizable carbon (POXC); 2) assess how prior crop and soil texture affect the relationship among these soil variables; and 3) determine which soil N availability measures are most strongly related to crop agronomic performance, such as corn grain yield, corn total N uptake, and corn grain N uptake. We have completed all the goals of this project and report here the final results.

2) ACTIVITIES PERFORMED AND OUTCOMES

Methods:

Twenty-seven sites in Minnesota used for corn N response trials were selected for sampling in April and May of 2014. The sites were located in 17 counties across Minnesota. Before corn was planted in May of 2014, the previous crops were alfalfa, soybean, and corn. Soil types from these sites ranged from sandy loam to clay, with clay contents from 23-48%. Samples were collected before planting or during early stages of vegetative growth. A total of 148 samples were collected from each of two depths (0-15 and 15-30 cm). In addition to conducting the Solvita test with duplicates for each sample, SOM, 2 M KCl extractable soil nitrate-N and ammonium-N, and permanganate oxidizable carbon (POXC) (Weil et al., 2003; Culman et al., 2012) were measured. For a subset of samples, we also conducted the standard aerobic incubation test to determine potentially mineralizable N (PMN or N_0), and N mineralized after 32 (N_{32}) and 64 (N_{64}) days (Stanford and Smith, 1972). Clay content was measured with a hydrometer (Miller et al., 1997). We used the 50% water-filled pore space wetting method for the Solvita kit tests (Franzluebbers et al., 2000).

To prepare the samples for analysis, all soil samples were dried at 35°C and ground to pass through a 2-mm sieve. Soil organic matter content was determined by using the loss on ignition method (Heiri et al., 2001).

Results:
Indices Related to Soil N Availability

The soils from the 27 sites had a wide range of values for SOM (1.1-9.8%), extractable N (6-61 ppm), Solvita (33-176 ppm C), and POXC (198-1262 ppm C) in the 0- to 15- cm depth increment. Values for the 15-30 cm depth were a little lower. The Solvita CO_2-C median results were about 15% of the POXC values and POXC was about 3.0% of the median SOM-C. These labile C measurements clearly represent only a small fraction of the total organic matter C.

For 148 soil samples at each of three depth increments (0-15, 15-30, and 0-30 cm), all four measures, SOM, Solvita, Extractable N, and POXC were very strongly related to one another (Table 1). POXC had the highest r value in relation to SOM at all depths and to Solvita and extractable N at the 15-30 cm and 0-30 cm depths. Solvita was most strongly related to extractable N in the surface 15 cm and SOM in the 15-30 cm depth. Previous studies have shown that POXC was more strongly related to soil organic carbon than other active C fractions are (Weil et al., 2003; Culman et al., 2012). Our results showed that r values for POXC vs SOM were the highest among all measures at all three depths, but Solvita values were also highly related (p<0.001in all but one case).

	0-15 cm (n=148)			15-30 cm (n=148)		
	Solvita	Extr.N	POXC	Solvita	Extr.N	POXC
SOM	0.22**	0.36***	0.79***	0.54***	0.42***	0.87***
Solvita		0.43***	0.35***		0.22**	0.51***
Extr.N			0.40***			0.52***

	0-30cm (n=148)		
	Solvita	Extr.N	POXC
SOM	0.42***	0.42***	0.87***
Solvita		0.39***	0.45***
Extr.N			0.53***

Table 1. Pearson correlation coefficients (r) representing relationships among soil measurements for 0-15 cm, 15-30 cm, and 0-30 cm depths. Level of statistical significance indicated as p < 0.05 (*), p < 0.01 (**), and p < 0.001 (***).

For a subset of the samples (n =45), PMN (No) values were determined, as well as total N mineralized during 32 and 64 days of incubation. SOM had the strongest relationship with PMN (r=0.46, p<0.001), followed by POXC (r=0.39, p<0.01) and Solvita (r=0.36, p<0.05) (Table 2). Although Solvita was not as strongly related to PMN as SOM and POXC were, it was very strongly correlated with extractable N, POXC, and N_{64} (p<0.001).

	0-15 cm (n=45)					
	Solvita	Extr.N	POXC	PMN	N_{32}	N_{64}
SOM	0.54***	0.60***	0.74***	0.46***	0.45**	0.56***
Solvita		0.58***	0.67***	0.36*	0.45**	0.50***
Extr.N			0.62***	0.27	0.36**	0.41**
POXC				0.39**	0.43**	0.52***
PMN					0.50***	0.80***
N_{32}						0.82***

Table 2. Pearson correlation coefficients (r) representing relationships between soil measurements and PMN for 45 samples at the 0-15 cm and PMN. Level of statistical significance indicated as p < 0.05 (*), p < 0.01 (**), and p < 0.001 (***).

Short term C mineralization has been identified in the literature as an inexpensive and quick method to predict N needs and corn agronomic performance (Haney et al., 2001; Franzluebbers et al., 2000). Though the Solvita test is easier and more cost-effective than laboratory incubations, our analysis suggests that SOM or POXC are correlated as well or better with measures of mineralized N (PMN, N_{32} and N_{64}) as the Solvita test, although all three were correlated with N_{64} at the 0.001% level. These findings contrast with previous studies that show CO_2 respiration is the best indicator for PMN (Franzluebbers et al, 2000; Schomberg et al., 2009; Culman et al., 2013), but are in line with others who have shown that POXC is as good or better (Morrow et al., 2016).

Cropping History and Soil Texture

Relationships between Solvita and other soil measures were analyzed based on previous crop histories and soil texture (Tables 3 and 4). For the 0-15 cm depth, the correlation between Solvita and SOM was significant only for the sites with alfalfa as a previous crop ($r = 0.28$, $p<0.05$). The relationships between Solvita and SOM were much stronger, for all cropping histories, at the 15-30 cm depth and thus for the 0-30 cm depth. These results suggest that measuring Solvita for the top 30 cm may, in some cases, give better assessments of soil health than just taking samples from the top 15 cm.

Solvita was strongly related to extractable N ($p<0.001$) for corn and soybean at 0-15 cm but not with corn at 15-30 cm. Not surprisingly, Solvita was not related to extractable N where the previous crop was alfalfa, since much of the N in this soil increment is likely in the organic fraction. POXC had a strong relationship with all measures for all previous crops at all depth increments (except for Solvita in soybean at 0-15 cm).

		0-15 cm			15-30 cm		
		Solvita	Extr.N	POXC	Solvita	Extr.N	POXC
Alfafa (n=56)	SOM	0.28*	0.36**	0.68***	0.55***	0.28*	0.83***
	Solvita		-0.10	0.33*		0.26*	0.52***
	Extr.N			0.32*			0.30*
Corn (n=44)	SOM	0.10	0.33*	0.67***	0.50***	0.41**	0.84***
	Solvita		0.60***	0.37*		-0.00046	0.38*
	Extr.N			0.48***			0.65***
Soybean (n=48)	SOM	0.12	0.15	0.93***	0.65***	0.60***	0.93***
	Solvita		0.46***	0.20		0.56***	0.62***
	Extr.N			0.19***			0.58***

Table 3. Pearson correlation coefficients (r) representing relationships among soil measurements at 0-15 cm and 15-30 cm depths for three previous crops (alfalfa, corn and soybean). Level of statistical significance indicated as $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***).

When we analyzed the relationships among these soil measurements according to clay content (Table 4), higher r values were observed for Solvita vs. SOM and extractable N in the coarser textured soils (Clay < 35%). However, p values were also significant, although lower, for the other two clay content categories, except for Solvita vs SOM for Clay > 45%.

		0-15 cm			15-30 cm		
		Solvita	Extr.N	POXC	Solvita	Extr.N	POXC
Clay > 45% (n=32)	SOM	0.29	0.30	0.61***	0.52**	0.31	0.59***
	Solvita		0.49**	0.47**		-0.11	0.29
	Extr.N			0.33			0.75***
35%< Clay <44% (n=80)	SOM	0.37***	0.30**	0.62***	0.38***	0.20	0.74***
	Solvita		0.26*	0.52***		0.12	0.41***
	Extr.N			0.40***			0.28*
Clay < 35% (n=36)	SOM	0.60***	0.25	0.76***	0.44**	0.55***	0.74***
	Solvita		0.69***	0.64***		0.67***	0.42*
	Extr.N			0.32			0.33*

Table 4. Pearson correlation coefficients (r) representing relationships among soil measurements at the 0-15 cm and 15-30 cm depths by soils with differing clay content (Clay>45%; 35% < Clay < 45%; and Clay<35%). Level of statistical significance indicated as $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***).

Crop Agronomic Performance

Soil organic matter, POXC, extractable N, and Solvita were all significantly related to corn grain yield for the control plots (0N added) we sampled at 0-15 cm depth, but at 15-30 cm and 0-30 cm, SOM and extractable N were the strongest correlates (Table 5). When comparing all the measurements for the PMN subset (n=45), POXC (r=0.45) and extractable N (r=0.44) had the strongest correlations with corn grain yield (data not shown). Solvita results were correlated with PMN and yield at the 5% level of significance.

		Grain Yield	**Grain Yield**	**Total N**	**Grain Yield**	**Grain N**
		(n=120)	(n =96)	(n=96)	(n=84)	(n=84)
0-15 cm	SOM	0.35***	0.28**	0.26*	0.35**	0.31**
	Solvita	0.32***	0.01	-0.05	0.28**	0.26*
	Extr N	0.31***	0.13	0.25*	0.31**	0.31**
	POXC	0.28**	0.31**	0.28**	0.23*	0.23*
15-30 cm	SOM	0.27**	0.16	0.15	0.27*	0.23*
	Solvita	0.07	-0.13	-0.15	0.18	0.15
	Extr N	0.19*	0.13	0.19	0.17	0.19
	POXC	0.15	0.12	0.15	0.09	0.09
0-30 cm	SOM	0.32***	0.23*	0.21*	0.32**	0.28*
	Solvita	0.24**	-0.09	-0.13	0.27*	0.24*
	Extr N	0.28**	0.15	0.26**	0.28*	0.28**
	POXC	0.22*	0.22*	0.22*	0.17	0.17

Table 5. Pearson correlation coefficients (r) representing relationships between soil measurements and crop agronomic performance, including grain yield, total N uptake by plant, and grain N at three depths: 0-15 cm, 15-30 cm, and 0-30 cm. Level of statistical significance indicated as $p < 0.05$ (*), $p < 0.01$(**) and $p < 0.001$ (***).

For sites with corn as the previous crop, corn grain yield increased with greater Solvita CO_2-C (r^2 = 0.54) and extractable N values (r^2 = 0.44), but corn grain yield was not related to Solvita or other soil measures when alfalfa and soybeans were the previous crop. Clearly, soybean and alfalfa, especially, contributed to higher corn yields in the control plots (Fig 1.), but these benefits of the previous legume crop were not reflected in higher values for the Solvita test. Perhaps because SOM values tended to be higher in the alfalfa cropped fields, the sensitivity of the Solvita test was poorer. In addition,, there was a much narrower range of Solvita values for the corn after alfalfa plots, which made a correlation less likely.

For the set of samples where we had grain N uptake data, these results showed the same patterns as grain yield in the relationships among soil measurements. At the 0-15 cm depth, Solvita, SOM and extractable N were correlated to grain N uptake at $p<0.001$ but SOM was the only related measure at the 15-30 cm depth (Table 5). For the sites previously planted to corn, grain N increased with higher Solvita values ($r^2 = 0.59$), but there was no relationship in the alfalfa and soybean sites (data not shown).

For total N uptake by the control plot corn plants, SOM, extractable N, and POXC were significantly related at the 0-15 cm depth (Table 5). There was no relationahip between Solvita and total N uptake. This is because total N uptake data was only available from plots of corn following alfalfa and soybean and did not include the plots in corn after corn. For corn following soybean and alfalfa, Solvita was not correlated to grain yield or grain N, so it is not surprising it was not related to total N uptake either. For the 15-30 cm depth increment, none of the soil measures were related to total N uptake.

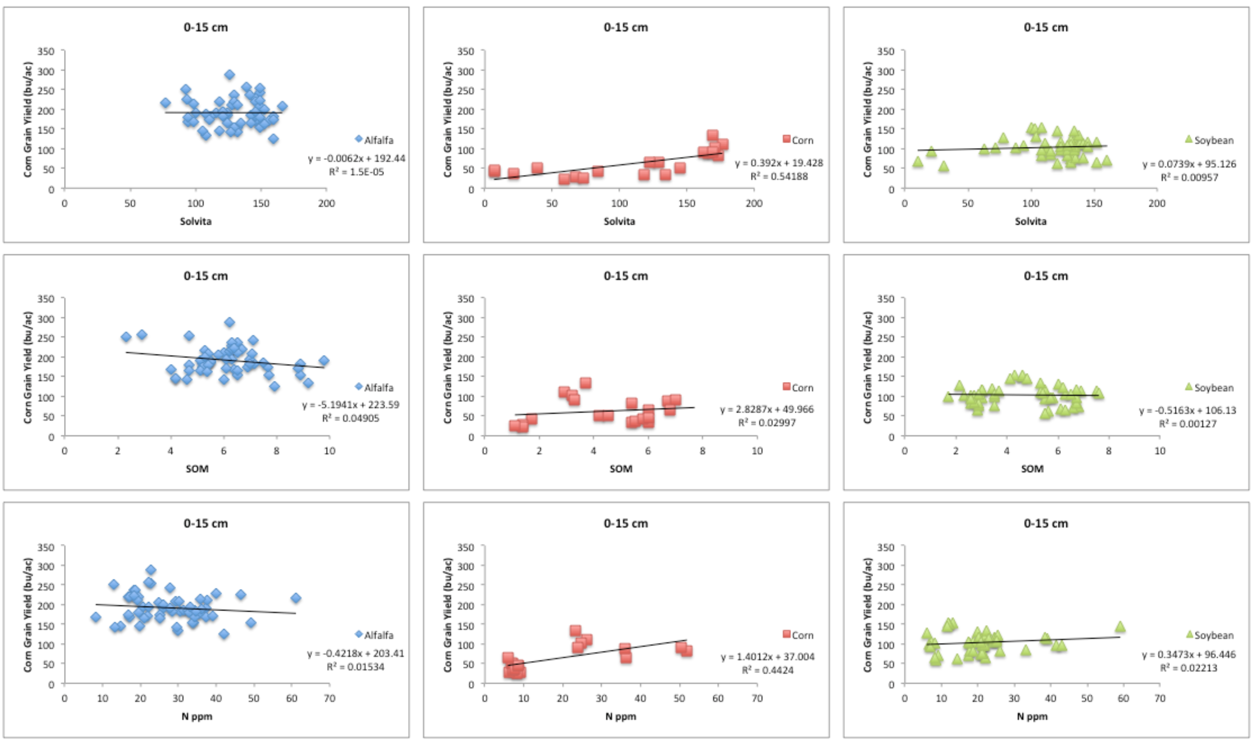

Figure 1. Relationship between corn grain yield and Solvita, SOM, and extractable N.

CONCLUSIONS

The Solvita CO2 burst test was strongly related to all other soil measurements used in this study, but did not prove to be the best predictor for PMN, as has been found in some previous studies (Franzluebbers et al., 2000, Schomberg et al., 2009; and Culman 2013). We found that POXC and SOM both were more strongly related to PMN than Solvita, although Solvita had as strong a relationship to N mineralized after 64 days as did POXC and SOM. Morrow et al. (2016) also found that POXC was a better predictor of mineralizable N than short term C mineralization. When considering previous crop history, we found that Solvita correlated with SOM but not extractable N in the top 0-15 cm when the previous crop was alfalfa, but was very strongly correlated with extractable N for sites previously cropped to either soybean or corn. Solvita had stronger relationships with other soil measures in the coarser textured soils (clay < 35%) than in soils with higher percent clay. In terms of agronomic performance, SOM, extractable N, and Solvita were equally good at predicting corn grain yield and grain N uptake in the top 15 cm, but SOM and extractable N were better indicators when the top 30 cm of soil were included.

Results from the 2013 growing season showed that PMN was more closely related to the Solvita results than to SOM (r=0.54 vs 0.34, n=19). For the 45 samples analyzed for PMN in 2014, PMN was more highly correlated to SOM and POXC than to Solvita (r=0.46, 0.39, and 0.36, respectively), although all three relationships were significant (p<0.001, 0.01, and 0.05). However, for the N mineralized after 64 days, the correlation coefficients for SOM, POXC and Solvita (0.56, 0.52, 0.50) were nearly identical and all were significant at the 0.001% level. Results so far do not suggest that Solvita is a better indicator of PMN than SOM or POXC, but in some cases may be a more accessible test. For the 120 field corn control plots, SOM, extractable N and Solvita were all equally well correlated with yield ($p < 0.001$), although SOM was the most strongly related when the 0-30 cm depth was considered. In this study, the Solvita test was well correlated with yield in corn after corn plots (as was extractable N) but not for corn after alfalfa or soybeans.

3.) CHALLENGES ENCOUNTERED AND LESSONS LEARNED

One big challenge in this research project was getting repeatable data with the Solvita test kit, but adjusting the method of rewetting the soil was able to improve repeatability substantially. It required too much labor to perform the nitrogen mineralization laboratory incubation for more than a third of the samples, but it would have been very useful information to have more of these analyses done. Interestingly, amount of N mineralized at 32 or 64 days after the incubation begins seems to be a more robust measure than the model-computed PMN (N_o) when incubations are as short as 64 days.

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