BIOCHEMICAL SOIL HEALTH INDICATORS RELATED TO ECONOMIC OPTIMUM NITROGEN RATE IN CORN

Daniela Orjuela-Díaz[1], Carrie AM Laboski[2], Francisco Arriaga[1]
[1]Soil Science Department, University of Wisconsin - Madison, WI, USA
[2]USDA- ARS, Pasture Systems & Watershed - University Park, PA, USA
orjueladiaz@wisc.edu (765) 775-9150

ABSTRACT

In corn production, nitrogen (N) fertilization is one of the main inputs to enhance yield. However, in the last few years, reducing N utilization has been a goal due to environmental concerns and production costs. Soil health tests have been studied to understand the relationship with N availability and its use to adjust N recommendation rates. The objective of this study was to evaluate the relationship of different soil tests with the economic optimum N rate (N) for corn in Wisconsin. Soil samples were analyzed from 24 sites in 2019 and 2020. Trials included treatments of corn yield response to different N rates. A total of six soil tests were conducted, total organic carbon (TOC), total carbon (TC), active carbon, soil respiration, ammonium content (NH4-N) at 0 and 7 days, and mineralizable N. Additionally, EONR and yield were determined for each site. Stepwise regression was used to select the best model to predict EONR across all sites. When evaluated alone, NH4-N at 0 days accounted for 64%, and soil respiration accounted for 40% of the variation in EONR across all sites. Stepwise regression selected the best model as the one that includes active carbon and NH4-N at 0 days, which accounts for 69% of the variation in EONR. The results of the regression models indicate ammonium content measured at 0 days to be a good predictor of EONR across the Wisconsin sites.

JUSTIFICATION

For farmers, it is important to decrease nitrogen use to maintain economic profit and avoid Nitrogen (N) leaching and contamination of the environment. Lately, there has been an interest in the use of soil health tests to predict N mineralization potential and further understand soil N availability.

The objective of this study was to evaluate bio/chemical soil health tests to predict economic optimum N rate (EONR) for corn in Wisconsin**.**

METHODS

In 2019 and 2020, 24 small plot field trials were conducted in 16 counties on private and university farms. Soil texture and drainage class, previous crop, use of cover crop, and manure history varied by site (Table 1). Corn grain yield response to sidedress N (0 to 224 kg N ha^{-1} in 40 kg N ha^{-1} increments at ~ V6; 4 replications) was evaluated. At each site, the EONR was calculated using a N: corn price ratio of 0.1 (eg. 0.4 $ per lb. N:4 $ per lb. grain) after fitting a model to the yield response data (quadratic plateau, linear plateau, or linear; best fit model chosen).

Soil samples (0-30 cm) were collected in the no N control plot within 3 days to planting. Samples were dried (32 °C) and ground (2mm) and analyzed for six bio/chemical soil tests: total organic carbon (TOC), total carbon (TC), and total N (TN) all analyzed on a LECO CN928 combustion analyzer; active carbon (permanganate oxidizable carbon, modified from Weil et al., 2003); soil respiration (CO_2 measured after 4 day incubation with sample rewet, CASH manual); initial NH_4 content (NH_4_0d) and NH_4 content after 7 days of anaerobic incubation at 40 °C (NH_4_7d), both extracted with 2M KCL and read with a spectrophotometer).

The relationship between EONR and soil tests were evaluated using correlation and forward stepwise regression analysis performed in R studio. The best model was selected using R^2 and adj R^2, BIC, AIC, and CP statistics.

Table 1. Twenty-one sites grouped by previous crop, texture, drainage, and manure history

Previous crop	Drainage Class	Texture	Manure	# Of sites
Soybean	W	Silt loam	No	2
			Swine	1
		Sandy loam	No	5
	MW	Silt loam	No	2
	SP	Silt loam	No	2
			Dairy	1
		Sandy loam	No	1
		Loam	Dairy	1
Corn	W	Silt loam	No	2
		Sandy loam	No	1
		Sandy	No	2

	MW	Loamy sand	No	1
Hemp	W	Silt loam	Turkey	1
Corn silage	MW	Silt loam	Dairy	1
Alfalfa	W	Silt loam	No	1

RESULTS

Three sites had NH_4 concentrations >13 ppm and appear to be outliers. At one site manure was applied a couple weeks prior to soil sampling, at another site banded N fertilizer was applied prior to sampling, and at the third site alfalfa was the previous crop. These conditions may have resulted in high NH_4 concentration and affected the correlation and model results.

Using stepwise regression with all data points, the best predictor was respiration with an Adj R^2=0.43 (Table 2), but when analyzed without the outliers the best predictor was NH_4 with and Adj R^2=0.64 (Table 3). The overall best predictor of EONR was the model that includes NH_4_0d and active carbon Adj R^2=0.68 (Table 3, Figure 1), when sites with >13 ppm NH_4 were removed.

Table 2. stepwise regression analysis using soil health tests to predict EONR 24 sites.

# Of Parameters	Test combination	R^2	Adj R^2	AIC	BIC	Cp	RMSE
1*	Respiration	0.45	0.43	259.5	261.8	-3.1	48.5
1	NH_4_7d	0.37	0.34	262.9	265.3	-0.4	52.1
1	TOC	0.36	0.33	263.3	265.6	-0.2	52.5
2	NH_4_0d+ TOC	0.48	0.43	261.3	263.9	-1.8	48.4
2	NH_4_0d + TC	0.47	0.43	261.3	263.9	-1.8	48.5
2	TOC + Respiration	0.47	0.42	261.4	263.9	-1.7	48.6
3	TOC + Respiration + TN	0.51	0.43	263.1	265.6	-0.8	48.2
3	TOC + TC + Respiration	0.50	0.43	263.3	265.9	-0.64	48.4
3	NH_4_0d + TOC+ Respiration	0.50	0.42	263.5	266.0	-0.5	48.6

*Indicates best model

Table 3. Stepwise regression analysis using soil health tests to predict EONR 21 sites

# Of Parameters	Test combination	R^2	Adj R^2	AIC	BIC	Cp	RMSE
1	NH_4_0d	0.64	0.62	220.4	222.1	1.3	40.5
1	Respiration	0.45	0.42	229.3	231.1	11.0	50.1
1	NH_4_7d	0.42	0.39	230.5	232.3	12.7	51.6
2*	NH_4_0d+ Active carbon	0.72	0.68	218.3	220.0	-0.67	36.8
2	NH_4_0d + respiration	0.70	0.67	219.3	221.0	0.02	37.7
2	NH_4_0d + TC	0.70	0.67	219.4	221.1	0.13	37.9
3	NH_4_0d + TC + ActiveC:TN	0.73	0.68	220.6	221.9	0.53	36.8
3	NH_4_0d + TOC + ActiveC:TN	0.72	0.68	221.1	222.3	0.82	37.2
3	NH_4_0d + TN + ActiveC:TN	0.72	0.67	221.3	222.6	1.00	37.5

*Indicates best model

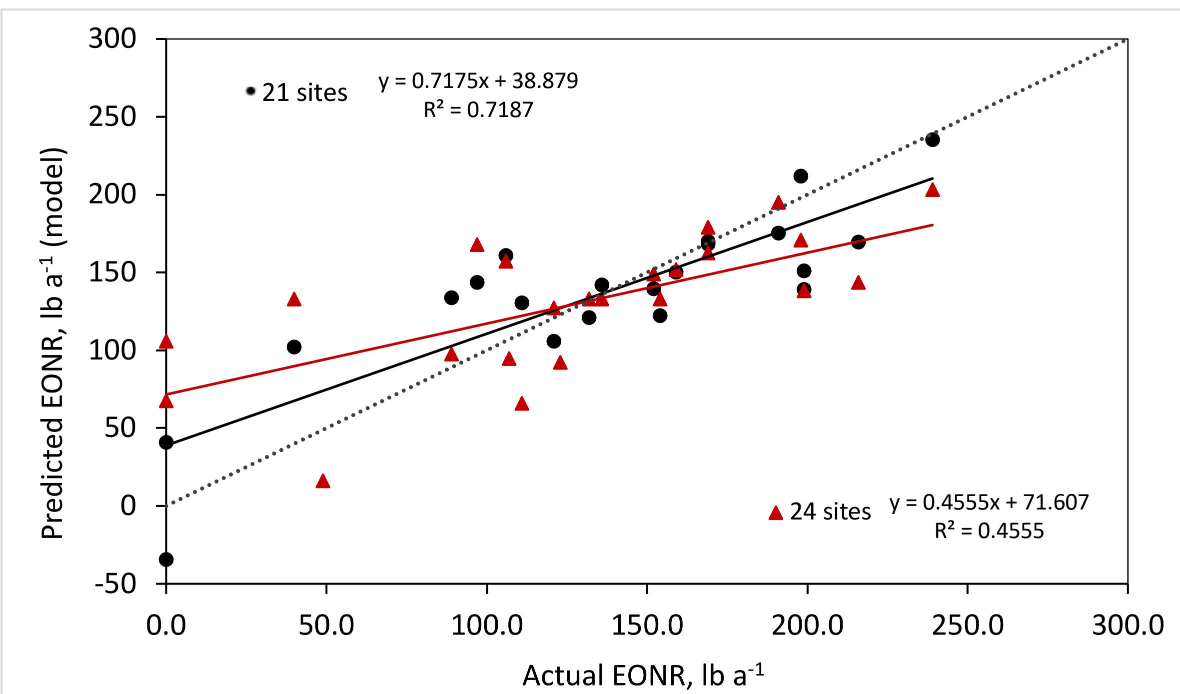

Figure 1. Actual EONR vs predicted EONR using outputs of the 21 sites model and 24 sites model.

CONCLUSION

The results from the stepwise regression analysis showed the best model to predict EONR is the one that uses NH^4 and active carbon soil tests since have the highest R^2 and Adj R^2, and the lowest AIC, BIC, and Cp statistics. This model can predict 68% variation in EONR, but it is important to highlight that this model has a modest increase in Adj R^2 compared to the prediction using only NH^4. According to the results, NH^4 is consistently present in most of the models that predict EONR better, so this can be an indication of how useful this soil test is to predict N availability in the soil. Additionally, it is important to notice that even when using more soil tests results the prediction of the models did not improve compared to the model with only one or two soil tests. These results show that N availability in soils can be assessed using fewer soil tests like NH^4, in combination with other soil health tests like active carbon and respiration. But the decision of which test to use could be based on the cost and the practicality of the test. For example, the soil respiration test is conducted using a four-day incubation, which could delay the results and not be useful to use in N recommendation adjustments.

ACKNOWLEDGEMENTS

Thanks to Jerry Clark, Carl Duley, Bill Halfman, Phil Holman, Dan Marzu, Steve Okonek, Jamie Patton, Scott Reuss, Kevin Schoessow, Ken Schroeder, Dan Smith, and John Jones for their assistance in this research project. This work was funded by the Wisconsin Fertilizer Research Council and the Wisconsin Corn Promotion Board

REFERENCES

Weil, R.R., R.I. Kandikar, M.A. Stine, J.B. Gruver, and S.E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. Am. J. Alternative Agric. 18(1):3–17.

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M Kurtz, D.W. Wolfe, and G.S. Abawi, 2016. Comprehensive Assessment of Soil Health – The Cornell Framework, Edition 3.2, Cornell University, Geneva, NY.