An Assessment of Soil Testing as it Relates to Corn Ear Leaf Nutrition in the Midwest

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Abstract

Soil testing for P, K and Zn for corn production the Midwest is based on the probability of crop yield response to an applied fertilizer and not on crop nutritional status. Results of three years of observational data from 98 field sites show soil test M3-K only predicted 26% of the variability in ear leaf K at growth stage R1-R2, whereas K base fraction (K_{BF}) predicted 44% of the ear leaf variability and 56% of the variability in the ear leaf K:Mg ratio. Soil M3-P was inconsistent in predicting ear leaf P, and M3-Zn was not correlated with ear leaf Zn. Over years soil M3-K/Mg ratio was highly positively correlated with ear leaf K, negatively correlated with ear leaf Mg and positively correlated with ear leaf K:Mg ratio. Further subsoil K_{BF} and M3-K/Mg were better correlated with ear leaf K and the K:Mg ratio than M3-K. These results show soil K_{BF} and M3 K/Mg soil test parameters are superior indicators of the nutritional K status of corn ear leaves over current methods. Results support the inclusion of soil K_{BF} and M3-K/Mg in assessing corn K nutrition and response to K fertilizer recommendations.

Introduction

Nutrient management across the Midwest primarily relies on soil testing for generating crop phosphorus (P), potassium (K), zinc (Zn) and lime recommendations. It is based on reference soil test method, field correlation and calibration, and the probability of grain yield response to an applied nutrient based on a measured soil test value (Westerman, 1990). Soil testing in North American as is currently employed, does not address optimization of crop nutrient levels, but is focused solely on the probability of crop yield response to an applied fertilizer nutrient.

A survey of corn ear leaf data 2011-2018 from testing laboratories across the Western corn belt indicates a relatively low occurrence of P deficiencies, but higher frequency of K and Zn deficiencies based on published Land Grant University guidelines. Results have noted ear leaf K deficiencies exceeding 50% of samples tested and values for Zn in ranging 20-30%. The objective of this paper was to assess soil test chemical properties and their relationship to corn ear leaf P, K Mg and Zn nutrition; and corn stalk K nutrition based on observational analysis of data collected from Midwest grower fields 2016-2018.

Materials and Methods

Observational research sites were established in fifty-one grower fields in 2016 and fifty-three in 2017 through 2018 across nine US states. Sites were selected based on a high yield environments, representing a range of soil textures and fertility environments. At each observation site four replicated plots, each six rows width by 30 feet in length, were install at after planting at corn growth stage V2-V3. Composite soil samples were collected representing

0-2", 2-6" and 6-8" from each plot and analyzed for $pH_{(1:1)}$; Sikora buffer pH; Mehlich 3 (M3) P, K, S, Ca, Mg, Na, and Zn; SOM-LOI, estimated CEC (CEC_{Est}), K base fraction (K_{BF}), and calculated soil M3-K/Mg ratio. Composite ear leaf samples based on 30 leaf collection at growth stage R1-R2 and analyzed for N, P, K, S, Mg, Ca, B, Mn, Cu, Zn, N:K, K:Mg and N:Mg ratios by Solum Labs, Ames, IA. At grain black layer grain yield data was collected by hand harvesting twenty feet of the center of the plot and collection of a composite of ten stalk segments 8" segment 6" above the ground. Grain moisture and test weight was determined and yield reported based on 15.5% moisture basis. Corn stalks were analyzed for: N, P, K, S, Mg, Ca, Zn and NO3-N by Sure-Tech Laboratories, Indianapolis, IN. For 2016 four sites were lost, one site in 2017 and two in 2018 due to weather and/or crop damage. Soil analyses, tissue data and yield data was compiled, averages calculated based on four reps, and analyzed using MS Excel and correlation models developed using XLstat software. Observation site data was processed as two data sets 2016 (n=47) and combined 2017-2018 (n=51).

Results and Discussion

Across 2016 observation sites soil pH values ranged from 4.90 - 7.63, M3-P 12.3 -105 ppm, M3-K 71 - 512 ppm, M3-Mg 64 - 1030 ppm, M3-Zn 0.6 - 29 ppm, SOM-LOI 1.40 - 5.35%, and CEC_{Est} 3.9 - 28.2 cmol kg^{-1}. For 2016 ear leaf concentrations for N ranged 2.07 - 3.32 %, P 0.24 - 0.46%, K 1.08 - 3.18%, Mg 0.14 -0.50 % and Zn 21.7 - 53.0 ppm. Similar soil analysis ranges were found for 2017 and 2018 observation sites, however ear leaf N nutrient concentrations were generally lower. Ear leaf P, K and Zn concentration ranges broadened in 2017-2018. Plant harvest populations ranged 26,800 to 34,200 plts ac^{-1} and grain yields ranged 145 - 282 bu ac^{-1} in 2016. Grain yields for 2017 and 2018 ranged from 176 - 292 bu ac^{-1}.

Pearson correlation coefficients for soil analyses and leaf nutrients for 2016 are shown in table 1. Soil $pH_{(1:1)}$ and M3-Zn were not correlated with ear leaf nutrients evaluated. Soil M3-P was significantly positively correlated with ear leaf P ($R = +0.62$, $p<0.0001$) and K ($R = +0.44$, $p<0.001$), whereas M3-K was significantly positive correlated with ear leaf P ($R = +0.48$, $p<0.001$), K ($R = +0.51$, $p<0.0001$) , and K:Mg ratio ($R = +0.67$, $p<0.0001$) and negatively correlated with ear leaf Mg ($R= -0.59$, $p<0.0001$) . Soil M3-Mg was significantly positively correlated with ear leaf Mg ($R = +0.55$, $p<0.0001$) and negatively correlated with the ear leaf K:Mg ratio ($R= -0.59$ $p<0.0001$) . Soil SOM-LOI and CEC_{Est} were both highly negatively correlated with ear leaf K with SOM-LOI values of ($R= -0.70$, $p<0.0001$) and negatively correlated with the ear leaf K:Mg ratios ($R = -0.57$, $p<0.0001$). K_{BF} was highly significant positively correlated with ear leaf P ($R = +0.56$, $p<0.0001$), K ($R = +0.67$, $p<0.0001$) and the K:Mg ratio ($R = +0.74$, $p<0.0001$) and negatively correlated with ear leaf Mg ($R= -0.58$, $p<0.0001$). Soil M3-K/Mg ratio was significantly positively correlated with ear leaf K ($R = +0.70$, $p<0.0001$) and K:Mg ratio ($R= +0.81$, $p<0.0001$) and negatively correlated with ear leaf Mg ($R= -0.64$, $p<0.0001$) .

Observation site results for combined 2017 and 2018 observation sites show similar soil analysis and plant correlations to those of 2016 (table 2). Soil M3-P and M3-K were significantly positively correlated with ear leaf K, with M3-K correlated with ear leaf K ($R = +0.53$, $p<0.0001$) and K:Mg ratios ($R = +0.48$, $p<0.0001$). Soil SOM-LOI and CEC_{Est} were significantly negatively correlated, with SOM-LOI correlated ear leaf K:Mg ratio ($R = -0.44$,

Table 1. Pearson correlation coefficient of nine soil parameters and corn ear leaf nutrients, 2016 observation sites.

Soil Analysis[1]	N	P	K	Mg	Zn	K/Mg
pH	-0.12	0.12	-0.26	0.25	-0.15	-0.27
M3-P	0.30	0.62***	0.44**	-0.17	-0.23	0.30
M3-K	0.10	0.48**	0.49**	-0.59***	0.01	0.67***
M3-Mg	-0.20	-0.04	-0.51***	0.55***	-0.20	-0.59***
M3-Zn	-0.13	0.25	-0.02	-0.20	-0.05	0.05
SOM-LOI	-0.33	-0.41*	-0.70***	0.40*	0.37	-0.57***
CEC_{Est}	-0.34	-0.40*	-0.61***	0.40*	0.37	-0.55***
Soil K_{BF}	0.36	0.56***	0.67***	-0.58***	0.29	0.74***
M3 K/Mg	0.37	0.37	0.70***	-0.64***	0.25	0.81***

[1.] * , **, *** are different from 0 with a significance level alpha=0.01, 0.001 and 0.0001, n =47 sites

Table 2. Pearson correlation coefficient of nine soil parameters on corn ear leaf nutrients, observation 2017 and 2018.

Soil Analysis[1]	N	P	K	Mg	Zn	K/Mg
pH	0.31	0.09	-0.07	0.25	-0.02	-0.21
M3-P	0.05	0.28	0.44*	-0.27	0.09	0.42*
M3-K	0.01	0.26	0.53***	-0.30	-0.03	0.48**
M3-Mg	-0.42*	0.00	-0.32	0.34	-0.26	-0.49*
M3-Zn	0.20	0.17	0.18	-0.03	0.55***	0.17
SOM-LOI	-0.40*	-0.15	-0.30	0.30	-0.13	-0.44*
CEC_{Est}	-0.53**	-0.10	-0.27	0.29	-0.24	-0.39*
Soil K_{BF}	0.35	0.16	0.66***	-0.52**	0.15	0.76***
M3 K/Mg	0.31	0.13	0.65***	-0.46**	0.16	0.73***

[1] * , **, *** are different from 0 with a significance level alpha=0.01, 0.001 and 0.0001, n= 51 sites.

$p<0.001$). Soil K_{BF} was highly positively correlated with ear leaf K ($R = +0.66$, $p<0.0001$) and ear leaf K:Mg ratios (R = +0.76, p<0.0001) , and negatively correlated with ear leaf Mg (R = -0.46, p<0.001). Soil M3-K/Mg ratio was highly significantly positively correlated with ear leaf K (R = +0.65, p<0.0001) and K:Mg ratio (R = +0.73, p<0.0001) and negatively correlated with ear leaf Mg (R= -0.46, p<0.001). Exceptions found for 2017-2018 observations from those of 2016 were a positive correlation of M3-Zn with ear leaf Zn (R = +0.55, p<0.0001) and negative correlation of CEC_{Est} with ear leaf Zn (R= -0.53, p<0.0001) .

Soil depth analysis of the 2016 observation sites indicates correlations of soil tests with ear leaf K, Mg and K:Mg ratios (table 3). Positive correlations of soil M3-K with ear leaf K increased with depth, but were negatively correlated with ear leaf Mg and ear leaf K:Mg ratio. Soil K_{BF} was highly significantly correlated with ear leaf K and K:Mg ratio independent of depth. Soil M3-K/Mg correlations generally increased with depth for ear leaf K, with a correlation of for the 2-6" depth (R = +0.66, p<0.0001). Soil M3-K/Mg correlations with ear leaf K:Mg ratio decreased with depth with the highest value noted for the 0-2" depth (R = +0.82, p<0.0001).

Corn stalk K analyses for 2016 and 2017-2018 observation sites show significant correlations with soil and ear leaf analyses (Table 4). Soil M3-K, K_{BF} and M3-K/Mg were positively correlated with stalk K concentrations for both observation data sets, where as soil CEC_{Est} was significantly negatively correlated only in 2016. Ear leaf K and K:Mg ratios were highly positively correlated with stalk K concentrations, with K:Mg correlations of R +0.73 and R +0.63 for the respective years.

Table 3. Pearson correlation coefficients for soil K and corn ear nutrients by soil depth, 2016.

Soil Analysis	Depth	Ear Leaf K	Ear Leaf Mg	Ear Leaf K/Mg
M3-K				
	0 - 2"	0.17	-0.25	0.33
	2 - 6"	0.35	-0.38	0.49**
	6 - 8"	0.48**	-0.35	0.58**
Soil K_{BF}				
	0 - 2"	0.66***	-0.47**	0.66***
	2 - 6"	0.68***	-0.42*	0.60***
	6 - 8"	0.70***	-0.35	0.58***
Soil M3 K/Mg				
	0 - 2"	0.63***	-0.59**	0.82***
	2 - 6"	0.67***	-0.55***	0.79***
	6 - 8"	0.66***	-0.48**	0.75***

[1] * , **, *** are different from 0 with a significance level alpha=0.01, 0.001 and 0.0001, n= 51 sites.

Table 4. Pearson correlation coefficients, six parameters for corn stalk K, 2016 and 2017-2018.

Analyses	Corn stalk K	
	2016 observation sites[1]	2017-2018 observation sites
M3-K	0.78***	0.52**
CEC	-0.46**	-0.35
Soil K_{BF}	0.73***	0.64***
M3-K/Mg	0.62***	0.54**
Leaf K	0.56**	0.55**
Leaf K:Mg	0.70***	0.63***

[1.] * , **, *** are different from 0 with a significance level alpha=0.01, 0.001 and 0.0001, n= 47 sites 2016 and 51 sites 2017-2018.

Table 5. Soil K_{BF} range, corn ear leaf K deficiency range and ear leaf K:Mg ratios 2016.

Soil K_{BF} Range	Corn ear leaf value	
	Mean percent of observation sites < 2.0% K	Mean ear leaf K:Mg ratio
< 1.5%	100	4.7
1.5 - 2.0 %	70	5.8
2.0 - 3.0 %	54	6.4
3.0 - 5.0 %	33	9.6
> 5.0 %	12	14.6

[1] 2016, 47 field sites, each K_{BF} range represent 7-9 observations sites, soil sample 0-8" depth collected spring 2016, ear leaves collected at GS R1-R2.

Summary and Conclusions

Results show that for ninety-eight Midwest corn grower observation sites M3-P was inconsistent with ear leaf P across the two data sets, but consistently positively correlated with ear leaf K. M3-K had a very significant positive Pearson correlation with ear leaf K and K:Mg ratios and a negative correlation with ear leaf Mg. These results are in agreement with those of Seggewiss and Jungk (1988), that showed that rye grass K deficiencies resulted in increase Mg uptake. Soil M3-Mg, was negatively correlated with ear leaf K, and ear leaf K:Mg ratios indicating high soil M3-Mg was associated with ear leaf K deficiencies.

Correlations of soil M3-Mg and M3-Zn with leaf Mg and ear leaf Zn were inconsistent across the two data sets and likely related to weather differences between years as early growing season rainfall was significantly higher in 2017 and 2018 relative to 2016.

Consistently results indicated positive Pearson correlations of both soil K_{BF} and M3 K/Mg with ear leaf K and ear leaf K:Mg ratios, and a negative correlation with ear leaf Mg. Across the two data sets correlations of either K_{BF} and M3-K/Mg with ear leaf K were higher than those observed for M3-K alone. Further both K_{BF} and M3-K/Mg were significantly correlated with stalk K concentrations across years. In addition high correlations were also noted for both soil K_{BF} and M3-K/Mg with ear leaf K observed across soil depths for the 2016 data set.

These results show soil K_{BF} and M3 K/Mg test parameters are superior in predicting ear leaf K and/or K:Mg ratios than the current M3-K soil test method used for K nutrient management. Further they advance the premise that soils with low K_{BF} values are associated with lower ear leaf growth stage R1-R2 concentrations and lower K:Mg ratios for results from the 2016 observation sites as illustrated in Table 5. Based on a ear leaf K critical deficiency concentration of 2.0%, observation sites with a $K_{BF} < 1.5\%$ had 100% of sites with ear leaf K deficiency and a mean K:Mg ratio 4.8, whereas sites with a $K_{BF} = 5.0\%$ had 12% of sites the ear leaves with < 2.0% K and a mean ear leaf K:Mg ratio of 14.6. Elwali et al. (1985), reported DRIS norms for corn grown in the southeastern US reported a mean ear leaf K:Mg ratio of 9.6 and that ratios < 6.0 were sub optimal and associated with corn K deficiencies. Observation data of 2016 from this study indicated sites with ear leaf K:Mg ratio > 10.0 resulted in a mean grain yield of 244 bu ac^{-1}, whereas those with a ratio < 6.0 had a mean corn yield of 212 bu ac^{-1}.

Overall, these observations indicate an inconsistent correlation of M3-P with ear leaf P and M3-Zn with and ear leaf Zn across years. M3-K as a soil test, only predicted 26% of the variability in ear leaf K, whereas K_{BF} predicted 44% of the ear leaf variability and predicted 56% of the ear leaf K:Mg variability. These results show the need to include soil K_{BF} and M3-K/Mg in the assessment of corn K response research and fertilizer recommendation models.

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