Potassium Nutrition and Soil Testing

Robert O. Miller
Colorado State University Fort Collins, CO

Tim J. Smith
Crop Smith Inc. Monticello, IL

Craig Struve
Soil View, Paulina, IA

December 6, 2017
Columbus, Ohio

http://gmoanswers.com/sites/default/files/corntatt.jpg/

My Background

5th Generation farm family in eastern Nebraska – 500 acres corn and soybeans

Affiliate Professor Colorado State University.
- Ph.D. Montana State University,
- Extension Soil Specialist UC Davis.

Conduct Regional Research in Soil Sampling, Soil Fertility, Lab Analysis and Coordinate the Agricultural Laboratory Proficiency (ALP) Program.

Miller, 2010

Overview

- Potassium Trends: Soil and Tissue
- Corn K Nutrition
- Field K Studies
- STK, Ear Leaf K and Yield
- Fertility Management

Miller et al, 2017

Soil Test K Trends

IPNI Report shows STK declining, In Ohio, Indiana and Michigan over the past 15 years.

State	STK Decline (ppm)	
	2005 - 2010	2010 - 2015
Ohio	- 23	- 20
Indiana	- 14	- 30
Michigan	- 18	- 19

IPNI, /soiltest.ipni.net .

Data from LGI Laboratory shows STK declining, Ellsworth Iowa.

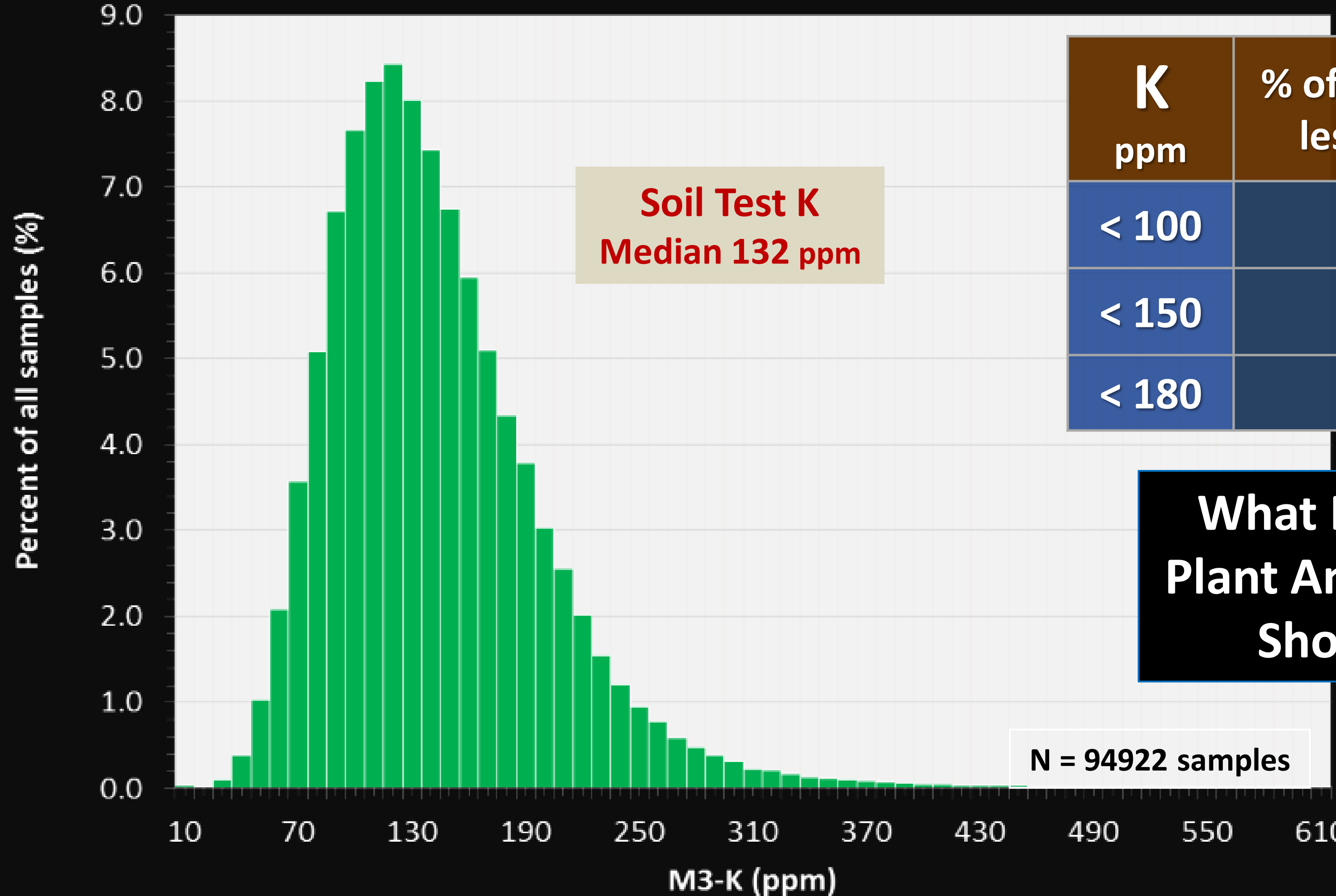
STK (ppm)	2007	2008	2009
< 130	30 %	35 %	42 %
< 170	58 %	63 %	68 %

Mean STK Dropping 6-7 ppm/yr

Miller et al, 2017

Soil Test K - Ohio

Potassium
19
K
39.0983



K ppm	% of samples less than
< 100	26.6
< 150	65.5
< 180	80.8

What Does Plant Analysis Show

[1] Source: Bill Urbanowicz, Spectrum Analytical, 2017.

Miller et al, 2017

Corn Nutrient Deficiencies - Indiana

Ear Leaf R1-R2, 3670 samples, six years

Nutrient	Deficiency threshold [1]	Percent of samples deficient [2]						Six year Average
	< Less Than	*2010*	*2011*	*2012*	*2103*	*2014*	*2015*	
N (%)	< 2.90	9.7	8.9	41.3	18.0	23.6	51.4	25.5 %
P (%)	< 0.30	8.3	12.1	49.2	15.3	8.1	36.5	
K (%)	< 1.90	41.5	30.8	67.0	32.0	36.2	16.7	37.4 %
S (%)	< 0.16	0.5	0.2	8.1	2.4	3.7	30.1	
Zn (ppm)	< 20	6.9	10.3	3.1	9.6	5.5	19.8	

[1] *Critical Nutrient level based on: https://www.extension.purdue.edu/extmedia/AY/AY-9-32.pdf Extension Bulletin E-2567 (New), July 1995*

[2] *Corn ear leaf GS R1-R2.*

CERES SOLUTIONS

Source: Betsy Bower, Ceres Solutions, Lafayette, IN

Miller et al, 2017

K Fertility

You can't resolve a problem unless you know its cause.

Robert Lustig UCSF, CA

Root Cause Analysis

Miller et al, 2017

Plant Potassium Nutrition

Crop Demand

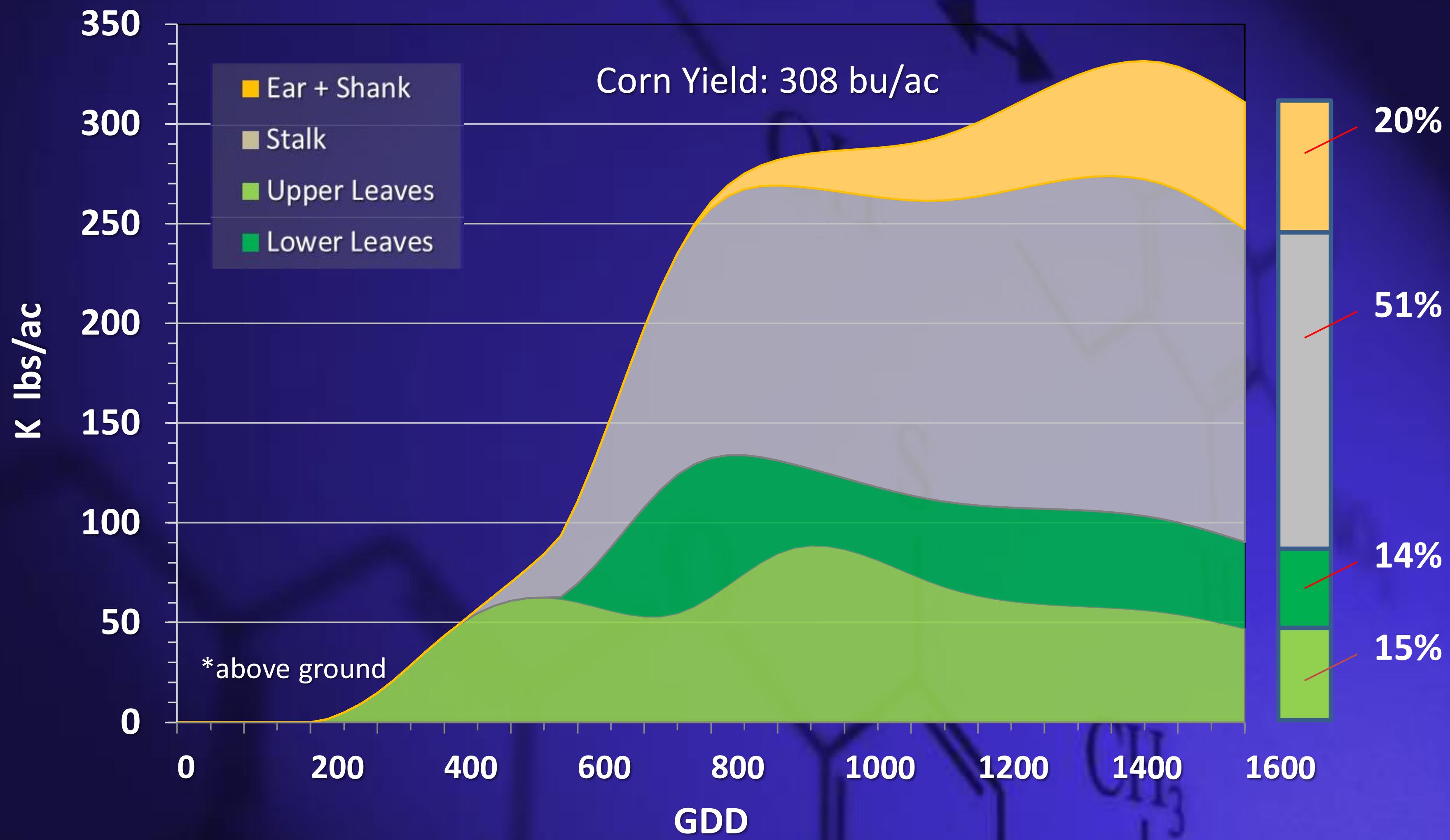
- Plant Nutrition
- Phenology of Uptake
- Plant Population

Soil Supply

- Soil Chemistry
- Nutrient Transport
- Stratification

Miller et al, 2017

Potassium Accumulation: Karlen et. al. 1988 [1]

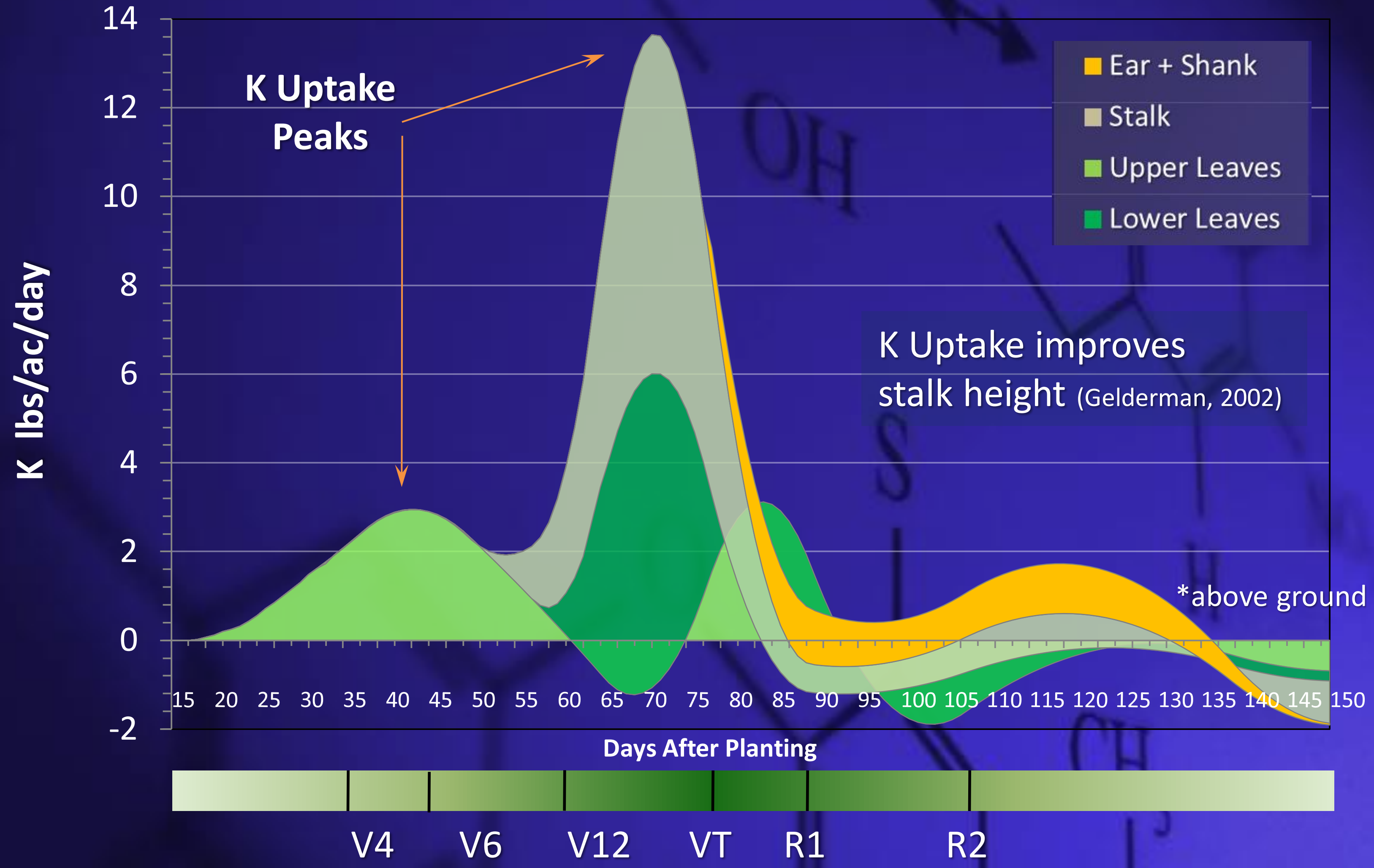


[1] *Calculated from: Karlen and Flannery. 1988. Agron J. 80:232-242.*

Miller et al, 2017

Corn Potassium Accumulation Rate [1]


www.udel.edu



[1] *Calculated from: Karlen and Flannery. 1988. Agron J. 80:232-242.*

Miller et al, 2017

Corn Population and Nutrient Uptake

Nutrient	Aerial Uptake grams per plant (g)	Estimated Uptake per 1000 plts/ac (lbs/ac)
N	3.8 □ 0.4	8.4 □ 1.0
P	0.8 □ 0.2	1.7 □ 0.9
K	3.1 □ 0.5	6.8 □ 1.0

[1] Source: Data review of published literature for corn populations ranging from 10,000 to 44,0000 plant per acre. : Sayre, 1948; Jordan et al 1950; Hanway, 1962; Rhoades and Stanley 1981; Karlen et al 1 1988; and Doberman, 2003.

Increasing corn population from 24,000 to 32,000 requires another 55 lbs/ac of K uptake.

Miller et al, 2017

Plant Potassium Nutrition

Crop Demand

- Plant Nutrition
- Plant Population
- Phenology of Uptake

Soil Supply

- Soil Chemistry
- Nutrient Transport
- Stratification

Miller et al, 2017

Soil Potassium Transport

Root Interception

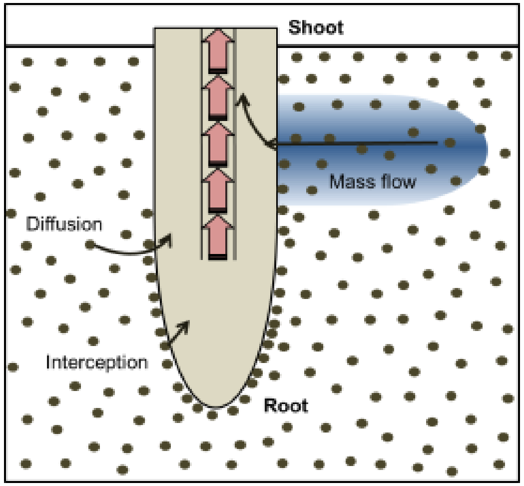
Direct root contact with soil K, 1-2% of total uptake.

Mass Flow

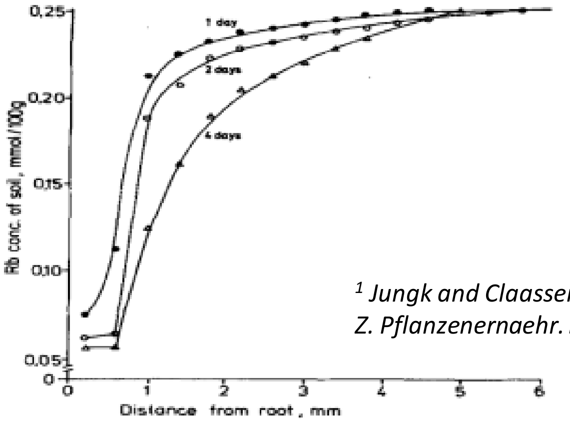
Soil solution K acquired through mass flow of soil water to plant root, 10-20% of total.

Diffusion

K movement down ion concentration gradient from bulk soil to root surface, 70-80% of uptake. Impacted by moisture.



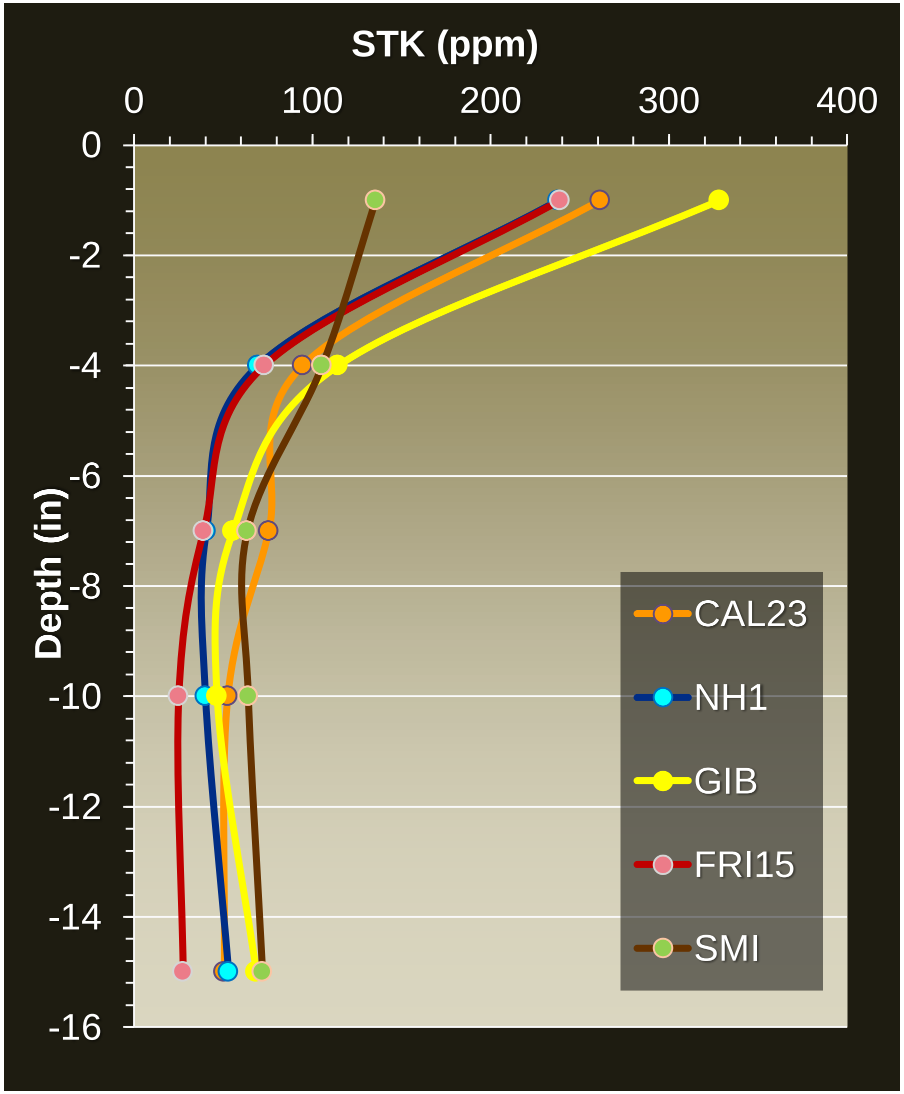
http://plantsinaction.science.uq.edu.au/sites/
plantsinaction.science.uq.edu.au/files/4.1-Ch-Fig-4.3.png



[1] Jungk and Claassen, 1986. Z. Pflanzenernaehr. Bodenk

Miller et al, 2017

STK Stratification – Five Sites 2014



STK consistently elevated at surface levels (> 3x subsoil) across 94% of KRx locations across four states.

Specific sites the 0-2" depth was 5X the content of the 6-8" depth. All sub soils had STK < 90 ppm.

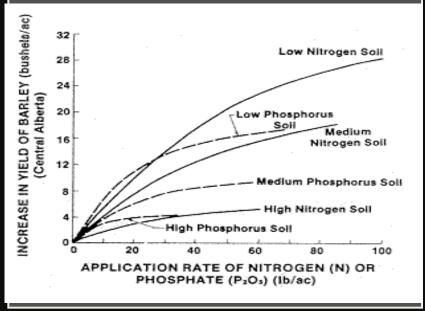
[1] 2014 KRx Project, SD, MN, IA, IL.

Miller et al, 2017

Soil Testing

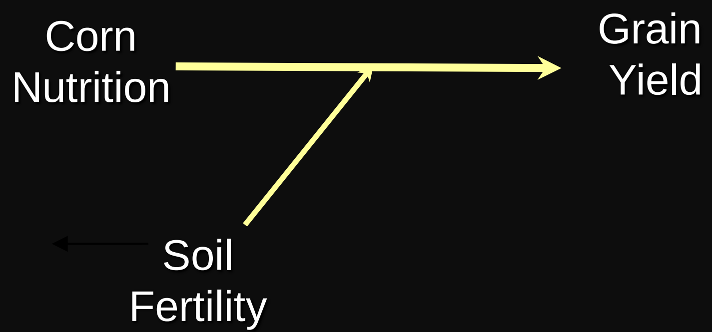
Lab Analysis

Calibration Data



Application

Root Cause Analysis



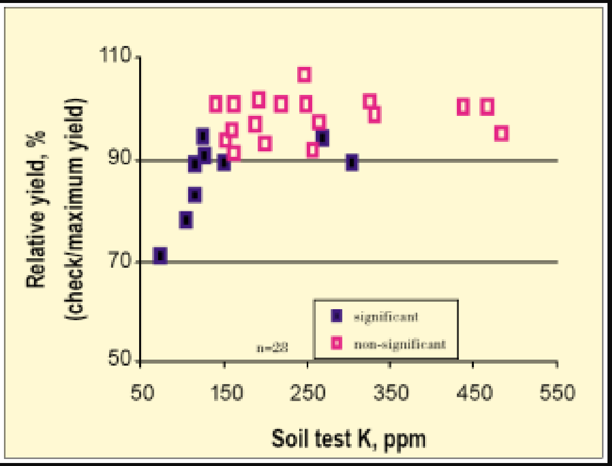
Miller et al, 2017

Nutrient Management

Soil

Soil Testing

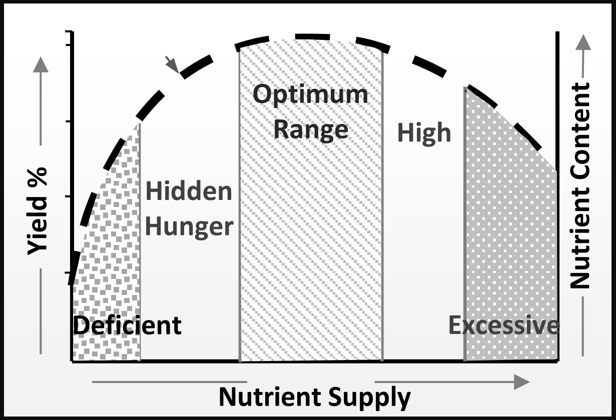
An evaluation of nutrient availability based on the probability of crop response utilizing a laboratory chemical extraction method. It has little to do with crop uptake or requirements.



Gerwing, Gelderman and Bly, 2003

Tissue Testing

Is an assessment of leaf/plant nutrient concentration based on a standard norm and historical observations.



Modified from Brown, J. R. 1970. Plant analysis. Missouri Agr. Exp. Sta. Bull. SB881

Miller, 2011

Miller et al, 2017

KRx Project

KRx project was launched in 2011 to evaluate grain yield response to applied K across six states based on the 4Rs approach.

Assess STK, ear leaf nutrient and K fertilizer on grain yield.

K Deficiency Winchester, Indiana, 2012 - Dave Taylor

Miller, Bower, Smith, 2015

KR$_X$ Corn Yield Response

KR*x* Project Yield Results 2012

six Illinois, Indiana and Nebraska sites.

Site	STK	Check	+K	Increase
Cty / State	ppm	bu/ac		
Merrick, NE	**151**	**169**	**170**	**+ 1**
Vermillion, IL	**131**	**174**	**176**	**+ 2**
Livingston, IL	**142**	**89**	**88**	**- 1**
Piatt, IL	**305**	**141**	**154**	**+ 13***
Sullivan, IN	**116**	**94**	**110**	**+ 16**
Warsaw, IN	**198**	**73**	**67**	**- 6**

* Yield significant at the 0.10 level, corn 15.5% moisture.
STK 0-6” Depth

K effect on ear size

K increased yield on a soil STK > 300 ppm

Miller, 2013

KR_X: N x K Corn Yield Response

2015 Yield Response to N and K

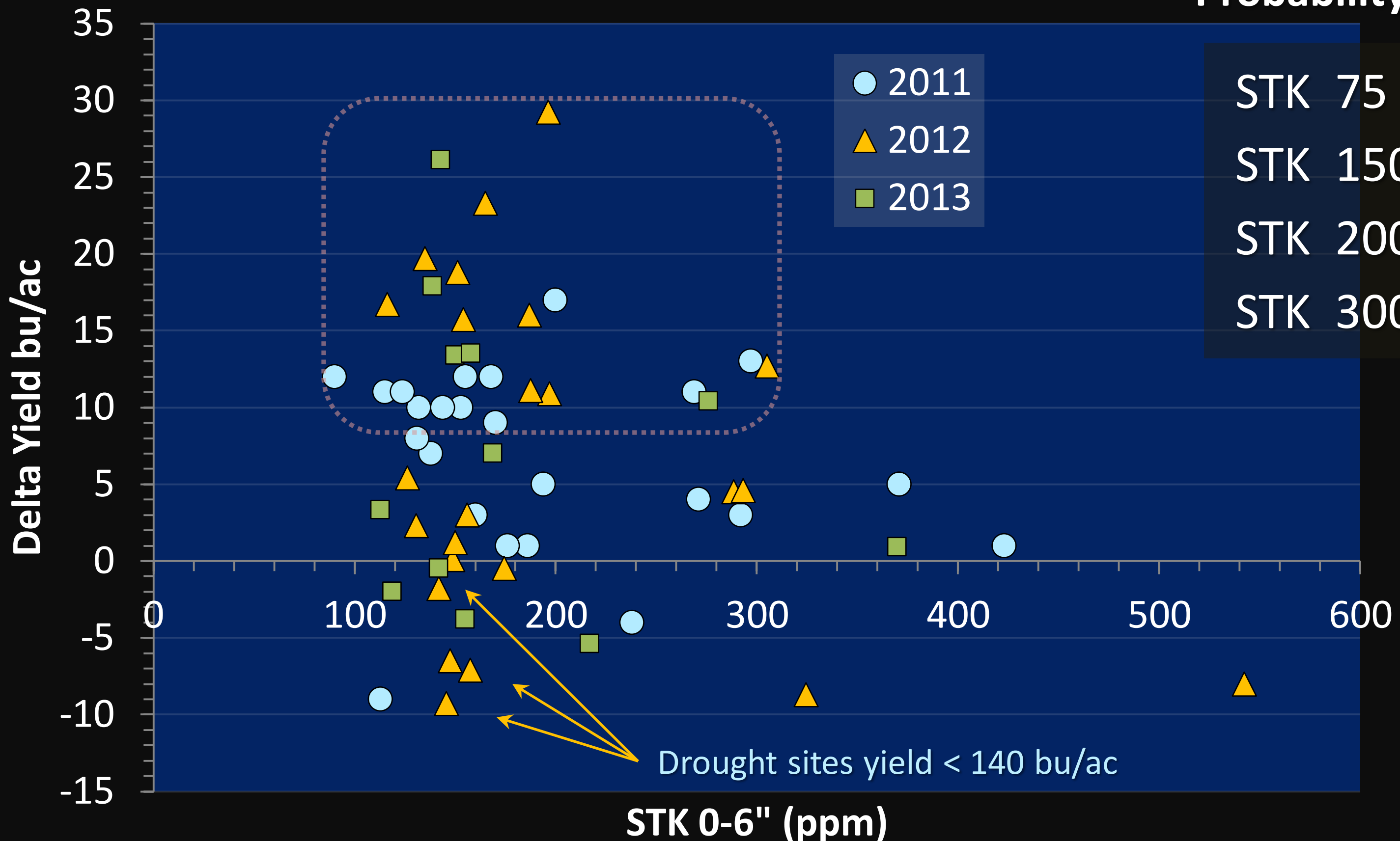
Treatment (lbs/ac)	*Iowa* *Sutherland*	*Wisconsin* *Dodgeville*	*Illinois* *Farmer City*
STK (ppm)	**192**	**178**	**154**
Check	**194**	**219**	**183**
50 K_{ac}	**206**	**231 ***	**187**
50 N	**217 ***	**230 ***	**200 ***
50 N + 50 K_{ac}	**212 ***	**239 ***	**195 ***

[1] *Treatments in the same column are significant from the check plot at p 0.1 level, 8 reps*

Miller et al, 2017

KR$_X$ STK vs Corn Yield - 3 years

A K application[1] improved grain yield at 28 of 60 locations.



Probability of yield response

STK 75 to 150	-	62%
STK 150 to 200	-	56%
STK 200 to 300	-	38%
STK 300 to 600	-	8%

Ave yield increase
11 bu/ac

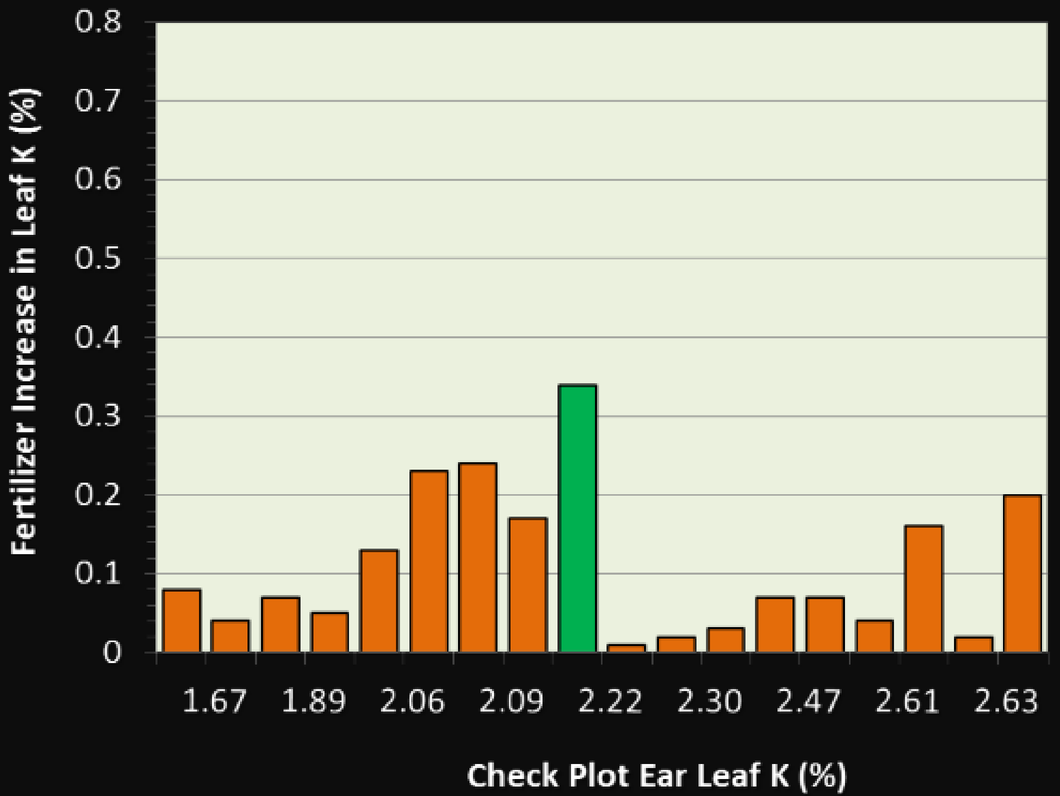
[1] Yield increase to application of 50 lbs/ac K at V3-V5.

Miller et al, 2017

Impact of Applied K on Ear Leaf K

www.hear.org/starr/images/image/?q=080914-9918&o=plants

2011, a K application[1] of 100 lbs/ac only increased ear leaf K significantly at 1 of 18 locations.



Similar results were found in 2012, 2013, 2014, and 2015.

In summary relatively no response in ear leaf K to applied K.

[1] K applied as KCl + KSO_4 at V5 using spoke wheel applicator.

Miller et al, 2017

STK vs Corn Yield

Premise of soil testing, that a lack of crop yield response indicates no nutrient deficiency.

However, just because there is no yield response does not mean that a fertilizer corrected a crop nutrient deficiency.

Questions

- ✓ **Does soil test K influence yield? Ear leaf K?**
- ✓ **Does ear leaf K impact yield?**
- ✓ **Due Soil factors (pH, SOM. CEC etc.) effect leaf nutrition?**

Miller et al, 2017

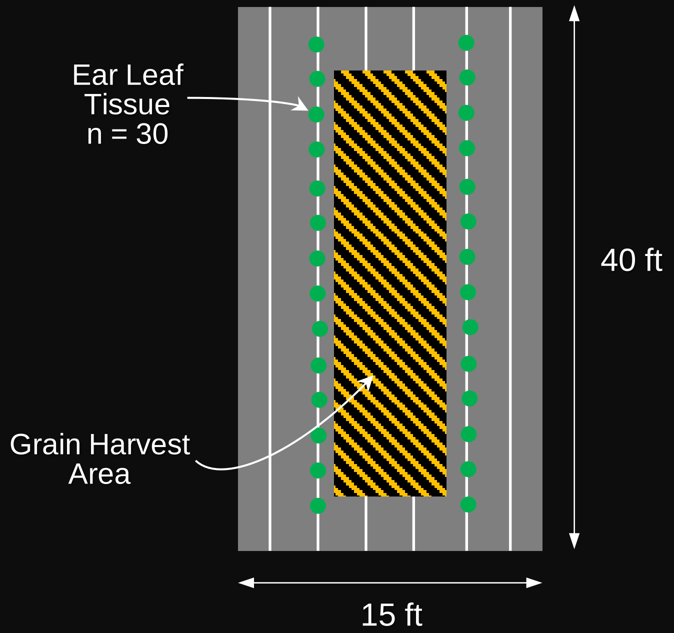
K_{RX} Research Database

2011-2015, 81 site studies were conducted in grower corn fields across 7 states. Check plot data: soil analysis (pH, P, K, Ca, Mg NO_3-N, P, SOM, CEC - 0-6”); ear leaf GS R1-R2 nutrients[1]; harvest population, grain yield; eight reps per site.

Sites diverse in: soil types, hybrids, fertility mgt, crop history, irrigated/dryland, and weather.

2016, 50 additional sites in seven states, added data collected on stalk nutrients, 4 reps/site. Cluster analysis and regression modeling.

Check plot diagram
Four per site



KRx Prescription Potassium

[1] Lab Analysis: LGI, Solum Laboratory and Sure Tech Labs.

Miller et al, 2017

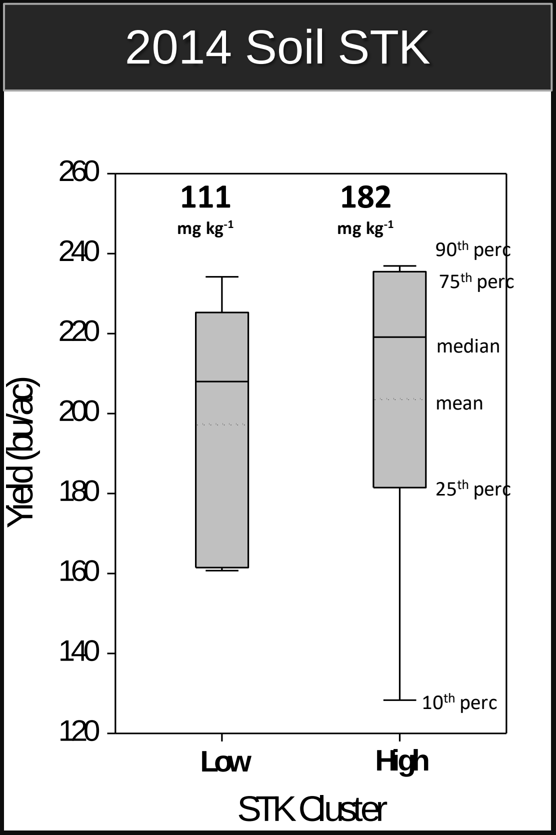
Cluster Analysis: STK vs Grain Yield

2014, 16 observation sites, 5 states. Data collected on M3-K, ear leaf nutrients and yield, M3-K sorted low to high.

	STK (ppm)	Yield (bu/ac)
Lowest	90	161
	100	234
	116	222
	122	162
	126	208
	128	131
	139	174
	141	183
	146	182
	151	188
	158	187
	163	128
	186	199
	187	237
	187	219
Highest	189	235

	STK	Yield
Mean	111	197
Stdev	16	34

	STK	Yield
Mean	182	204
Stdev	11	45



Box Whisker Plot

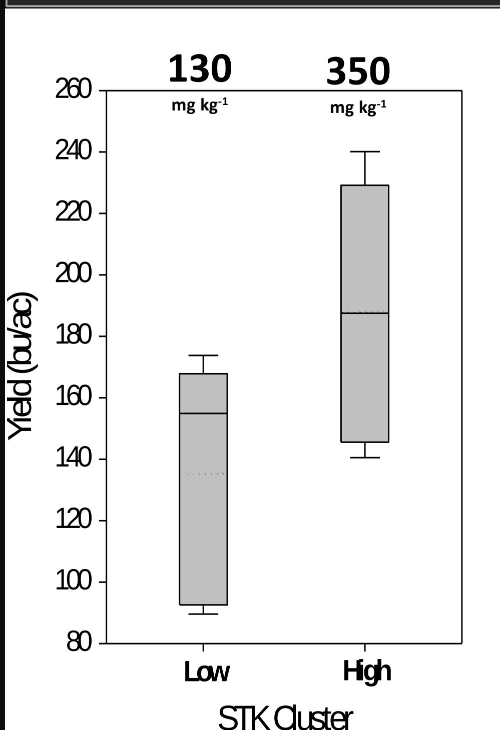
[1] Cluster analysis contrasting five lowest sites and five highest sites for Mehlich 3 K 0-6” response variable grain yield, 8 reps per site.

Miller et al, 2017

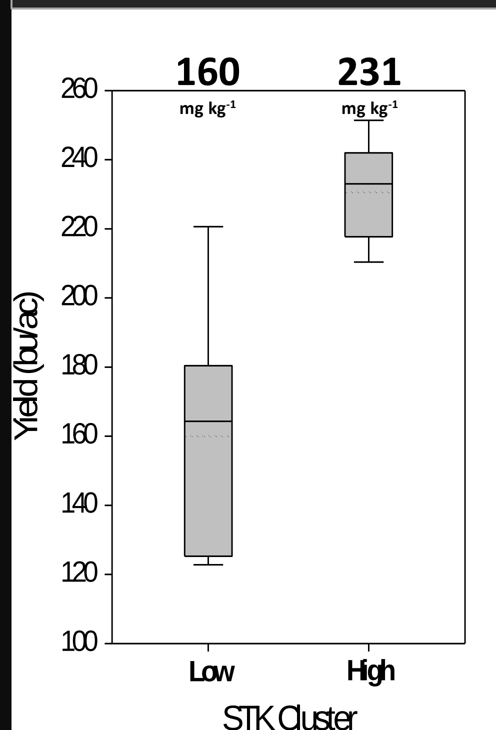
Cluster Analysis: STK and Yield

Box Whisker plot STK cluster[1] comparisons variable grain yield, 3 years.

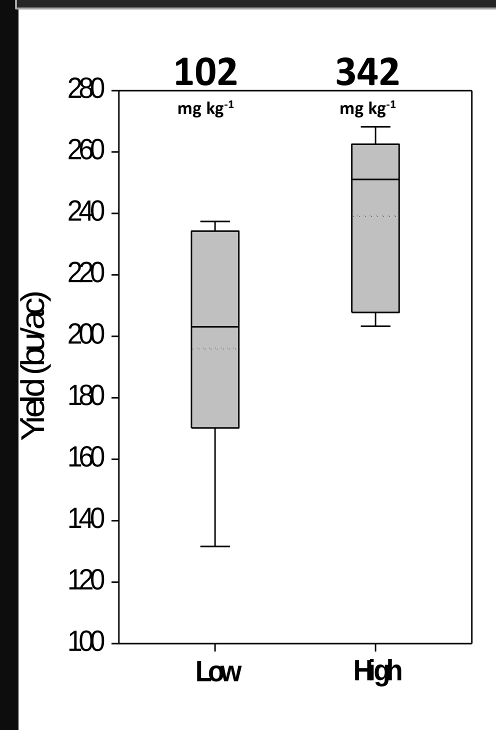
2012 Soil M3-K



2013 Soil M3-K



2016 Soil M3-K



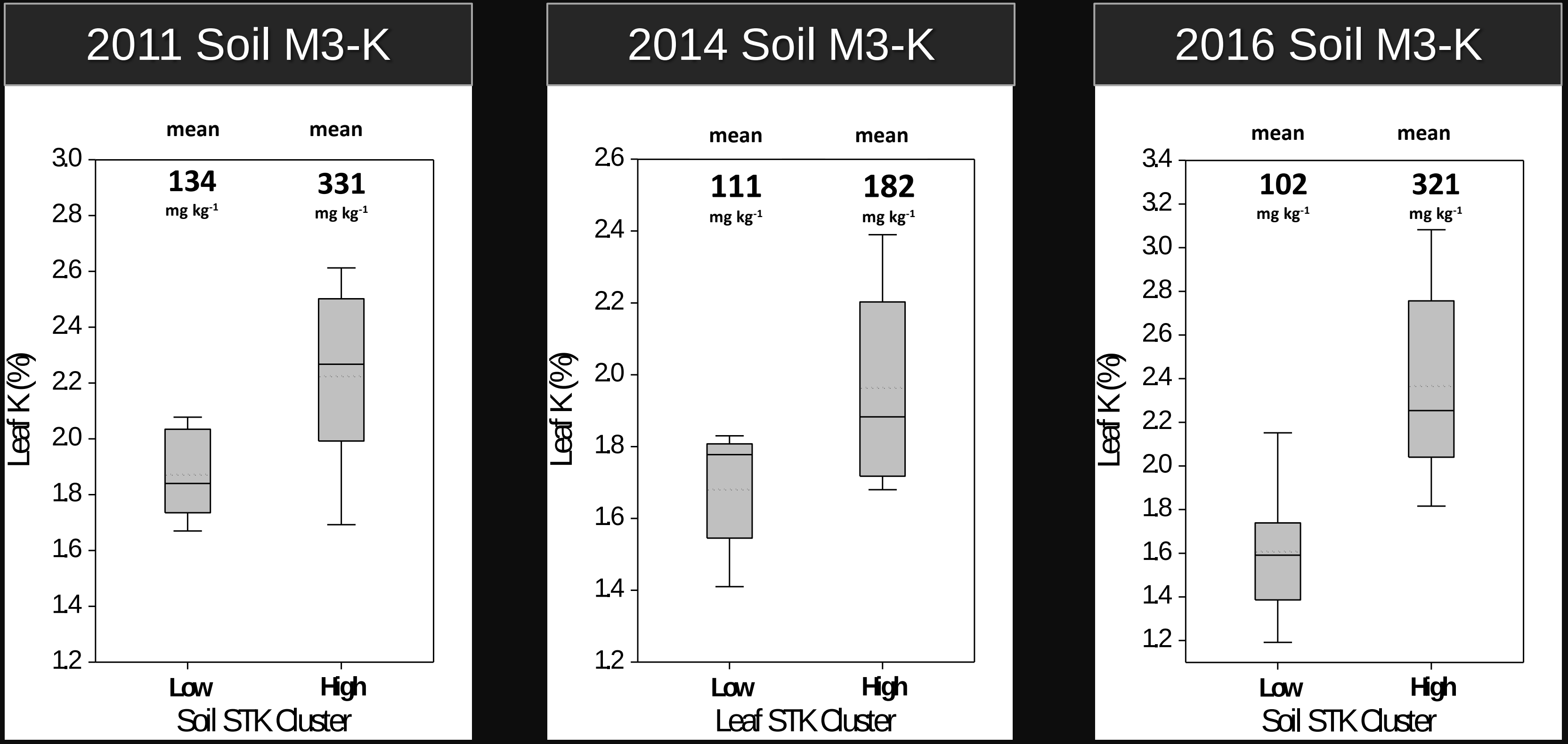
[1] Cluster analysis contrasting five lowest sites and highest sites for Mehlich 3 STK 0-6 in response variable grain yield.

Miller et al, 2017

Cluster Analysis: STK vs Leaf K

www.hear.org/starr/images/image/?q=080914-9918&o=plants

Box Whisker plot soil M3-K cluster[1] comparisons for variable ear leaf K for three years.



[1] Cluster analysis contrasting five lowest sites and highest sites for Mehlich 3 K 0-6” response variable corn ear leaf K R1-R2.

Miller et al, 2017

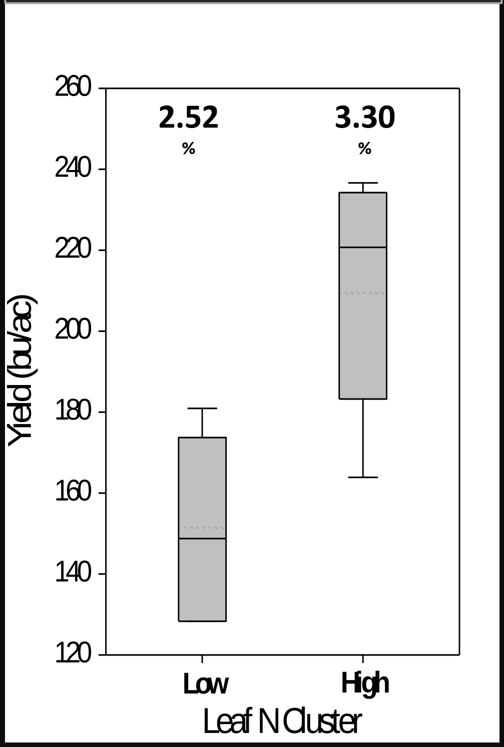
2014 Ear Leaf Nutrients Cluster Analysis

www.hear.org/starr/images/image/?q=080914-9918&o=plants

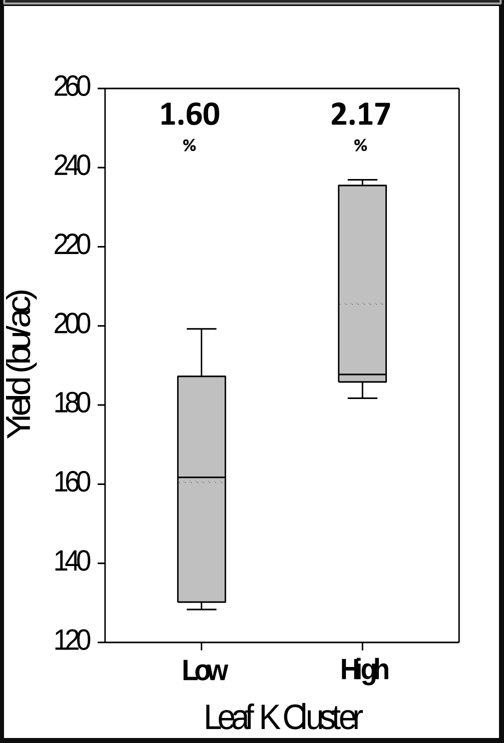
Box Whisker plot nutrient cluster[1] comparisons

Variable grain yield – 2014, 16 sites, cluster size 5 sites each

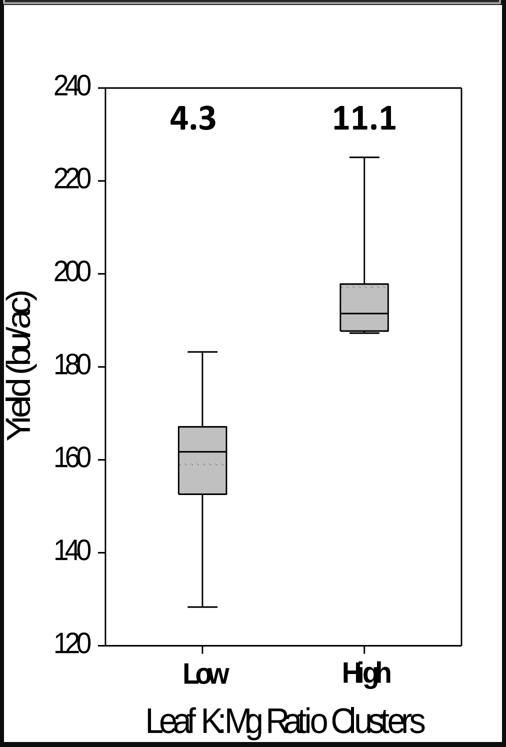
Leaf N



Leaf K



Leaf K:Mg



[1] Cluster analysis based on five lowest sites and highest sites for each test parameter (Leaf N, K and K:Mg), response variable grain yield, 8 reps per site.

Miller et al, 2017

Leaf K Cluster Analysis 2014

Cluster [1] comparisons – 2014 Sites
16 sites, cluster size - five sites each

Parameter	Low K Cluster		High K Cluster	
	Mean	*Stdev*	Mean	*Stdev*
N %	**2.80**	*0.51*	**2.95**	*0.27*
K %	**1.60***	*0.16*	**2.17**	*0.14*
Mg %	**0.34***	*0.04*	**0.23**	*0.03*
K:Mg	**4.8***	*2.2*	**10.2**	*1.8*
N:Mg	**8.4***	*1.5*	**13.3**	*1.7*
Yield bu ac^{-1}	**160***	*21*	**210**	*23*

[1] Sixteen sites, each cluster five sites, differences *significant at 0.05 level.

Low K clusters show significant increases in Mg, and declines in K:Mg and N:Mg ratios associated with lower grain yields.

Leaf diagnostic norms reported by Elwali et al. (1985) show the normal range K:Mg of 10.0 ± 4.2 and N:Mg value 14.1 ± 3.7 .

Low leaf K clusters K:Mg and N:Mg are outside normal range.

Miller et al, 2017

Summary: Ear Leaf K Cluster Analysis

132 sites, 2011 – 2016 cluster mean comparisons

Year	*Mean Ear Leaf Low K cluster* [1]		*Mean Ear Leaf High K cluster*		Yield Difference
	K %	K:Mg	K %	K:Mg	bu ac $^{-1}$
2011	1.77	5.9	2.64*	11.1*	40.5
2012	1.52	3.2	1.91	6.7*	58.2*
2013	1.67	3.0	1.95	8.3*	34.6
2014	1.60	4.8	2.17*	10.2*	49.5*
2015	-	-	-	-	-
2016 [2]	1.47	3.6	2.93*	14.2*	44.1*

*[1] Clusters comparisons five sites in 2011, 2012 and 2014; four in 2013; and eight 2016. No data 2015. * values are significant at the 0.05 level*

[2] 2016 Data based on 46 sites, seven states.

45.2 ← **Five year mean**

Cluster comparisons show mean leaf K and K:Mg ratios are different.

Cluster yield differences were consistent.

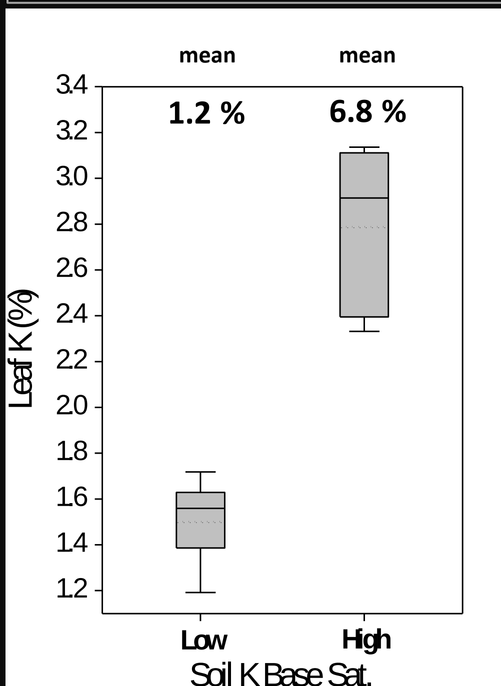
Miller et al, 2017

Cluster Analysis Soil Properties 2016

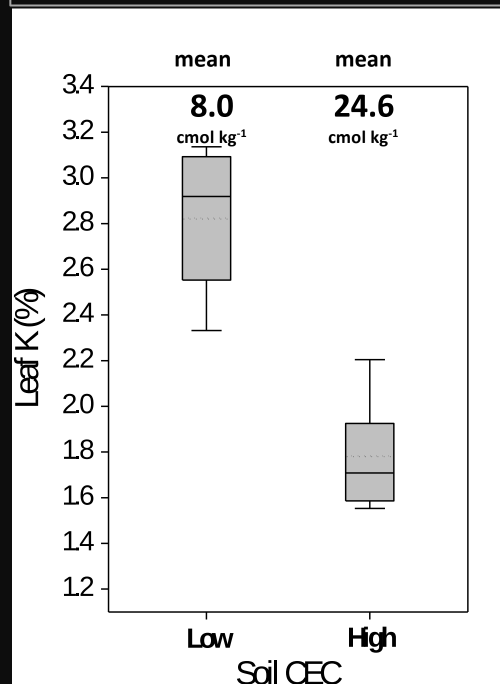
http://corn.agronomy.wisc.edu/Management/L011.aspx

Box Whisker plot soil test parameters[1] comparisons
Variable ear leaf K, 2 clusters, size - 8 sites each

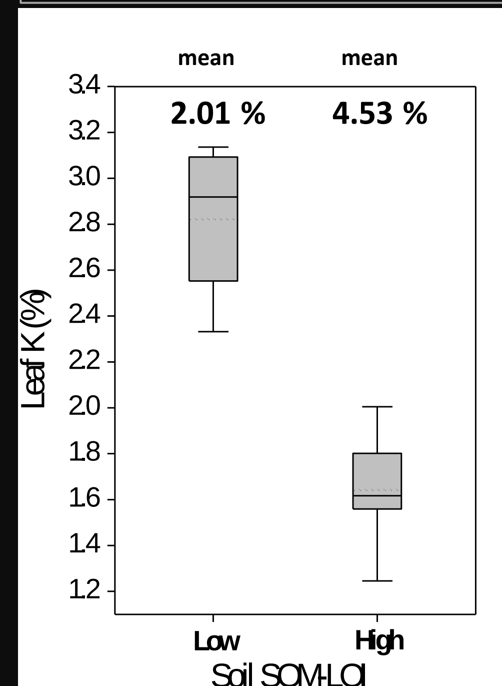
K Base Sat.



CEC



SOM-LOI [2]



[1] Cluster analysis contrasting eight lowest sites and highest sites for soil variables 0-20 cm depth, response variable ear leaf K R1-R2. (CEC by summation).

[2] Regression of CEC = 5.6(SOM-LOI) - 1.0, R^2 0.864

Miller et al, 2017

Soil K Base Sat Cluster Analysis

http://extension.missouri.edu/explore/images/ipm1007crabgrasslarge01.jpg

K Base Sat. Cluster comparisons - 2016 Sites

Variable[1]	Soil K Base Saturation (%)			
	Low Cluster		High Cluster	
	Mean	*Stdev*	Mean	*Stdev*
K Base Sat (%)	**1.2**	*0.2*	**6.8 ***	*1.7*
CEC (cmol kg^{-1})	**23.4**	*3.5*	**11.7 ***	*4.7*
SOM (%)	**4.28**	*0.58*	**2.40 ***	*0.50*
M3 K/Mg (meq)	**0.05**	*0.01*	**0.43 ***	*0.26*
Leaf K (%)	**1.50**	*0.20*	**2.62 ***	*0.32*
Stalk K (%)	**0.97**	*0.55*	**2.51 ***	*0.67*
Grain (bu/ac)	**202**	*26*	**240**	*11*

[1] Forty-six sites across seven states, K base sat cluster size eight sites each.
[2] * Mean values are significant at the 0.05 level.

Cluster analysis of soil K Base Sat. shows significant differences for soil CEC, SOM, K:Mg ratio.

Low soil K Base Sat. was associated with low leaf K, stalk K and lower grain yields.

Grain yield, although associated with higher leaf K, is a function of factors (H_2O, N, Pest, etc) that impact grain fill.

Miller et al, 2017

Multi Linear Model of Leaf K

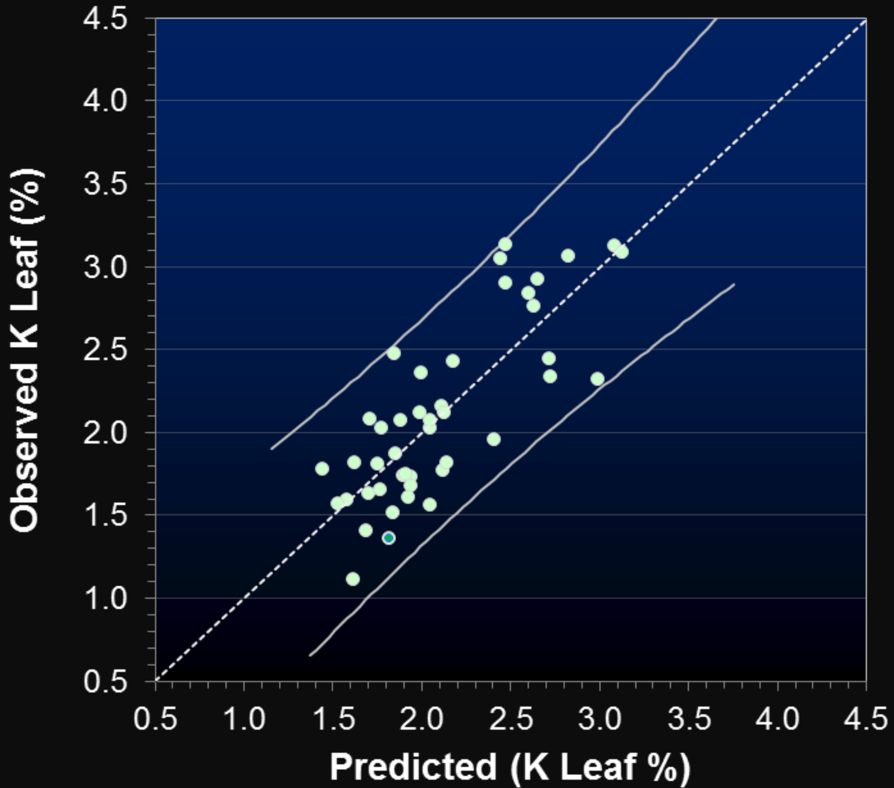
Regression analysis[1] shows ear leaf K is associated with K Base Sat, SOM and M3 K/Mg ratio.

K Leaf = 2.6 - 0.24^x^(SOM) + 0.022^x^(K Base Sat) + 1.05^x^(M3 K:Mg)

R^2 0.652

Inter collinearity is noted between SOM and K Base Sat.

Although positive correlation of K base saturation and M3 K/Mg ratio with leaf K has a rational basis, the negative correlation of SOM is confounding.



[1] Forty-six sites 2016 across seven Midwestern states.
Linear model for M3-K for Leaf K R^2 0.242

Miller et al, 2017

Soil K Base Sat. Ranges

Soil K Base Sat. Range	Parameter	
(%)	**Percent of ear leaves < 2.0% K**	***Average Grain Yield (bu/ac)***
< 1.5	100 %	205
1.5 – 2.0	70 %	222
2.0 – 3.0	54 %	236
3.0 – 5.0	33 %	244
> 5.0	12 %	245

[1] 2016, each K base sat range had 7-9 observation sites, soil sample 0-6" depth collected spring 2016, ear leaves collected at R1-R2 growth stage.

Cluster analysis of soil K Base Sat. shows significant impact on leaf K concentration and overall average grain yield.

Note data is diverse as it represents 46 observations collected across seven states ranging in soil types, management and hybrids.

Miller et al, 2017

Summary of Field Observations

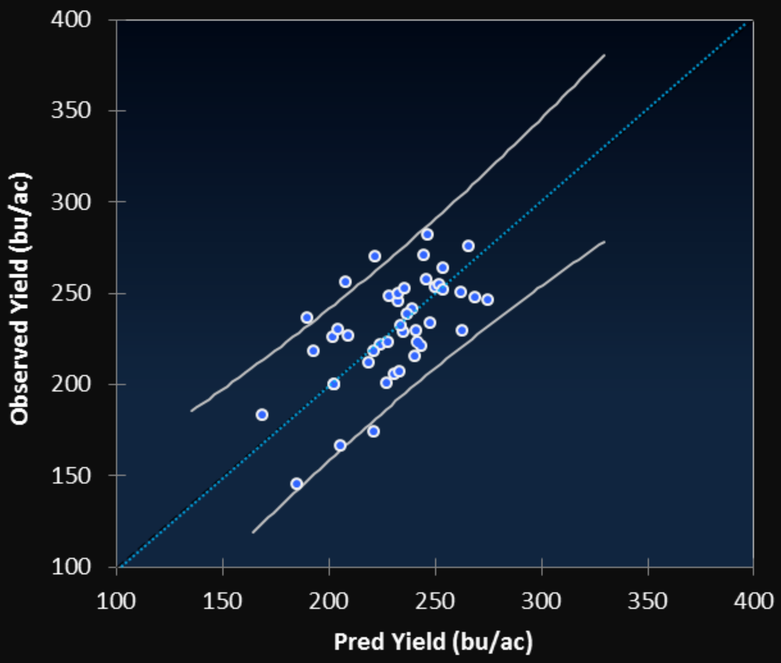
Additional Research planned for 2018 in IA, SD, IL, MN, and NE.

- ✓ M3-K minor association with grain yield and corn leaf K.
- ✓ Corn ear leaf K clusters > 1.9% and K:Mg > 8 are associated with higher grain yields, averaging 45.2 bu ac^{-1} over 5 yrs.
- ✓ Soil K Base saturation is positively correlated with ear leaf and stalk K, whereas CEC, SOM and M3-Mg levels are negatively correlated with ear leaf and stalk K.
- ✓ Low ear leaf K:Mg associated with 70% lower stalk K and 15% lower grain yields, 2016.

Miller et al, 2017

Grain Yield Observations 2016

- Ear leaf **N** explained 48% of grain yield across 46 sites with highest yields with leaf **N** of 2.9 -3.3 %, growth stage R1-R2.
- Cluster analysis of ear leaf **Zn** showed a yield difference of 48 bu/ac with highest yields with **Zn** concentrations of 35-45 ppm.
- Ear leaf **N** and **Zn** accounted for 58% of grain yield variation in a multiple linear regression model.



Miller et al, 2017

Addressing K Deficiencies

Soil Factors Impacting Ear Leaf K

- Soil K base saturation, < 3%.
- Stratification, low sub soil M3-K, < 125 ppm.
- High soil M3-Mg, > 500 ppm.
- Soil Moisture V5-V10. A 50% decrease in soil moisture decreases K diffusion >80%, facilitating Mg uptake.

Miller et al, 2017

Recommendations

Management Tool	Recommendation	Optional
Potassium Soil Test	✓	
Sub Soil K Test		✓
Tissue Test	✓	

<u>Assess K Base Sat levels.</u> K Base < 3% indicate possible response. Assess sub soil K at 10-20% of grid points.

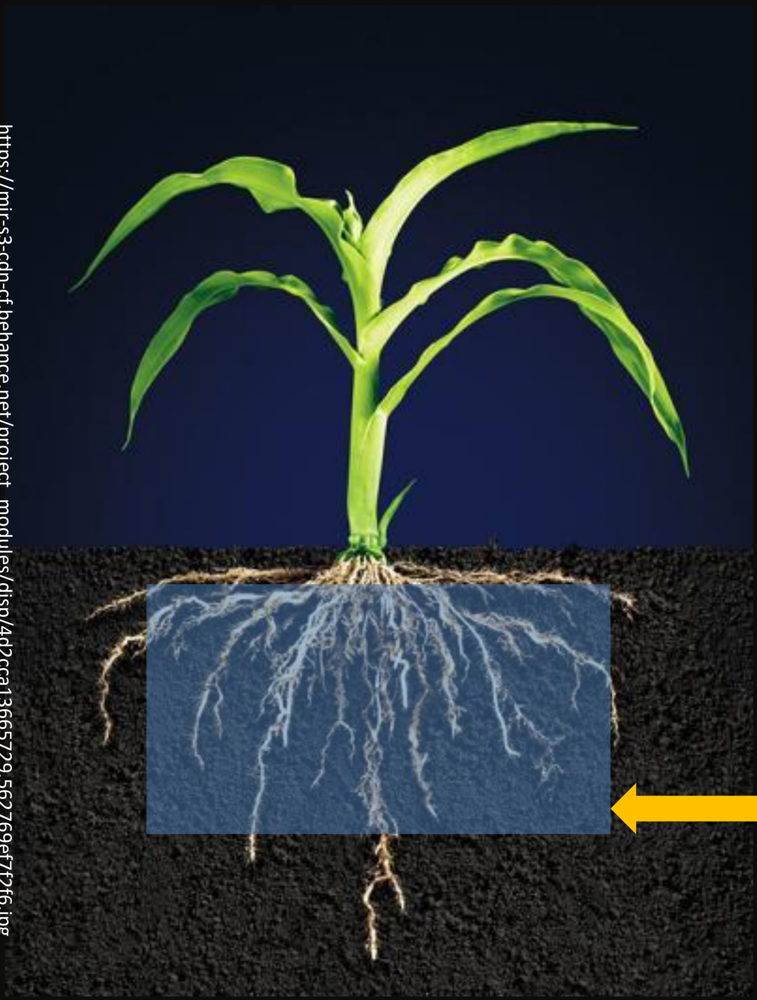
<u>Plant Analysis</u>. Confirm fertility, ear leaf (VT-R1) K < 1.9%, K:Mg ratios < 8 and N:Mg ratios < 10 are indicative of K deficiencies. Track five grid points/field, assess K management.

<u>Corn Stalk Analysis</u>. Low stalk K < 1.5% indicates low plant K uptake.

<u>Focus K fertilizer on subsoil applications.</u> Surface broadcast applications do little - **side dress**. . Don't expect K Base Sat or leaf K to change in 1 year, longer term 2-4 yrs.

KRx Prescription Potassium

Recommendations



https://mir-s3-cdn-cf.behance.net/project_modules/disp/4d2cca13665729.562769ef7f2f6.jpg

No Till - avoid surface K broadcast.

Reduce till systems, pre-plant in the row of dry K or liquid materials applied 2x2 or 2x4. 100 lbs/ac K applied 6” wide band over row pre-plant achieves 500 lbs/ac.

Side dress banding of liquid products (KCl, K_2SO_4 or K acetate) at V2-V5 is an option. Adding small amount of N is advised.

Zone of K enrichment. Focus on increasing K base saturation in V3-V6 root zone.

Miller et al, 2017

Special Thanks to our Grower Cooperators, Students and Staff who have assisted with this project.

Miller et al, 2017

Sponsors

Acknowledgements

Betsey Bower, Ceres Solutions, IN

Mike Lindaman, Ag Source – LGI Lab, IA

Tom McGraw, MISS, IA retired

Larry May, Lincoln, NE

Randy Brown, Winfield Solutions, NE

Jodi Jaynes, Sure-Tech Laboratories, IN

Nick Koshnick, Climate Corp, CA

Dave Mowers, Consulting, IL

Robert Beck, Winfield Solutions, IL

Mark David, Compass Minerals, ID

Tommy Roach, Nachurs, TX

Tim Eyrich, Agri-Trend, SC

Ray Ward, Ward Laboratories, NE

Scott Fleming, Rock River Labs, WI

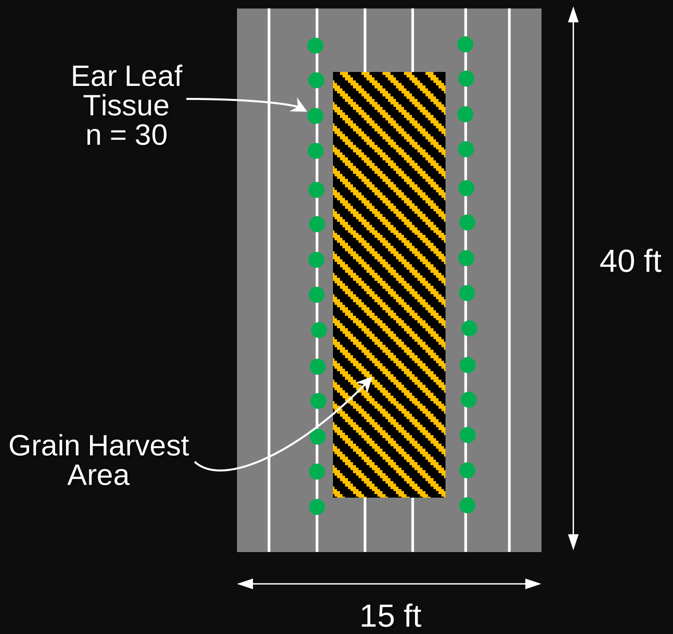
Research 2017 and 2018

2017 – Soil, tissue, stalk and yield data has been collected on an additional 23 sites and is being compiled.

2018 – Research will target Midwest sites based on soil K base sat, SOM and K/Mg ratio to verify predicted leaf K and yield results.

Evaluation of alternative methods of K application, products and timing.

Check plot diagram



[1] Lab Analysis: LGI, Solum Laboratory and Sure Tech Labs.

Miller et al, 2017


Thank you for your time
and attention