Sidedressing Potassium and Nitrogen on Corn

Evaluations made on yield effects.

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Summary: *Results of a Midwestern population study across five sites show optimum yields were obtained with planted corn populations of 32k-36k plants ac^{-1} based on 30" rows in the Midwest. Higher populations resulted in reduced number of plants with ears and lower grain yields. Side dress nitrogen (N) was site and year specific with an average response of 30 bu ac^{-1} to 50 lbs N ac^{-1} on the most responsive sites. Sidedress response to potassium (K) was limited, and the average response to sidedress applied K was 10-12 bu ac^{-1} with 50 lbs K ac^{-1}. K source product studies showed K acetate combined with N showed significant grain yield response. Cluster analysis of corn ear leaf nutrients collected at growth stage R1-R2 from 112 grower fields from 2011 to 2016 across six states, indicate leaf K levels <1.9% are indicative of lower yields and that K deficient fields show increased magnesium (Mg) accumulation resulting in lower ear leaf K:Mg ratios. Across five years low ear leaf K clusters averaged 45.2 bu ac-1 less grain yield than those with >2.0 leaf K. Established N, K, Mg DRIS ratio norms for corn leaves are an effective tool in diagnosing corn K deficiencies, their impact on grain yield, and addressing long-term K fertility management of corn.*

Soil testing is the foundation for nutrient management decisions, the reliability of which is based on a representative sample, an appropriate test method, and the nutrient calibration crop response model. Agronomic corn production practices in the Midwest have advanced significantly over the past thirty years, with improved hybrid genetics, decreased tillage, increased plant populations and refined N management resulting in higher yields. Over this period, corn grain yields have increased an average of 2.5 bushels per acre per year.

While N fertility management has generally kept pace with increased corn plant populations and yield, that for K has remained relatively unchanged. Increasingly, K deficiencies have been noted. A survey of ear leaves from Ceres Solutions in Indiana from 2011 to 2013 indicates K deficiencies ranged from 15.3 to 57.3 (Miller, 2014) and were significantly more than any other nutrient. Soil fertility results from a survey of Midwestern soil testing labs by the International Plant Nutrition

Table 1. Corn harvest populations for three sites 2015 for four plant populations.						
Planted Population (Plts ac^{-1} x 1000) [1]	Grain Yield (bu ac^{-1})					
	Summerland, IA		Dodgeville, WI		Farmers City, IL	
	Ave	Stdev	Ave	Stdev	Ave	Stdev
26 k	25,650	1160	25,480	800	20,850	2810
32 k	30,860	1010	30,370	1950	27,980	1680
38 k	36,385	1180	35,950	1110	33,090	2550
44 k	40,730	1190	41,550	1340	36,730	4260

[1] Planted population based on planter seed John Deere counter, harvest population based on stand counts 3/1000th of an acre of plants with ears at black layer.

Table 2. Influence of fertilizer N and K on grain yield across four corn populations at Sutherland, IA site 2015.

Treatment 123	Grain Yield (bu ac^{-1})			
Plants ac^{-1} x 1000	26 k	32 k	38 k	44 k
Check	192.9	201.1	204.3	194.6
40 N	196.4	206.8	204.5	197.8
50 K	181.6	205.2	198.3	188.8
40 N + 50 K	196.4	206.1	204.8	199.8
VN	189.0	214.2 *	216.7 *	196.6
VN + 50 K	186.0	203.2	211.4	198.7

[1] Fertilizer sources: Nitrogen urea; and K acetate rates lbs ac^{-1}.
[2] VN variable N rate adjusted as function of population, increasing 7.0 lbs per thousand plts ac^{-1} above 26k.
[3] Results followed by (*) are significant at the 0.05 level from the check treatment, six replications.

Table 3. Influence of fertilizer N and K on grain yield across four corn populations at Dodgeville, WI site 2015.

Treatment 123	Grain Yield (bu ac^{-1})			
Plants ac^{-1} x 1000	26 k	32 k	38 k	44 k
Check	235.3	237.1	237.2	226.1
40 N	236.1	240.1	242.1	224.7
50 K	237.7	242.9	239.1	236.5
40 N + 50 K	238.0	241.4	244.2	231.8
VN	243.7	236.9	241.7	223.0
VN + 50 K	232.7	238.6	241.8	229.7

[1] Fertilizer sources: Nitrogen urea; and K acetate rates lbs ac^{-1}.
[2] VN variable N rate adjusted as function of population, increasing 7.0 lbs per thousand plts ac^{-1} above 26k.
[3] Results followed by (*) are significant at the 0.05 level from the check treatment.

Table 4. Influence of fertilizer N and K across grain yield four corn populations at Farmer City, IL site 2015.

Treatment 123	Grain yield (bu ac^{-1})			
Plants ac-1 x 1000	26 k	32 k	38 k	44 k
Check	144.2	171.7	177.4	78.9
40 N	142.5	182.7	175.3	88.9
50 K	151.8	182.3	170.4	86.1
40 N + 50 K	146.4	178.4	172.4	79.8
VN	153.8	173.0	194.4	111.8
VN + 50 K	135.2	175.6	185.5	109.7

[1] Fertilizer sources: Nitrogen urea; and K acetate rates lbs ac^{-1}.
[2] VN variable N rate as function of population, increasing 7.0 lbs per thousand plts ac^{-1} above 26k.
[3] Results followed by (*) are significant at the 0.05 level from the check treatment.

Table 5. Influence of fertilizer N and K grain yield across three corn populations at Wellington, CO site 2015.

Treatment 123	Grain yield (bu ac^{-1})		
Plants ac^{-1} x 1000	34k	41k	48k
Check	112.9	116.7	129.4
50 N	130.0	151.8	168.2*
50 N + 50 K	141.8*	156.8*	207.3*

[1] Fertilizer sources: Nitrogen urea; and K acetate rates lbs ac-1.
[2] VN variable N rate as function of population, increasing 7.0 lbs per thousand plts ac^{-1} above 26k.
[3] Results followed by (*) are significant at the 0.05 level from the check treatment.

Institute (IPNI) (Fixen et al 2010) indicate soil test K (STK) values have declined 24 lbs/ac^{-1} across the corn producing states over a five year period.

Increasingly, corn growers have shown interest in sidedress application of N fertilizers, which improve efficiency and minimize losses. Vegetative growth uptake of N and K are generally paired in a ratio of 1:0.8 (Karlen et al, 1987), thus the application of both N and K during early vegetative growth stages is more likely to improve corn yield than N alone.

Objectives

Among the objectives of this research project are to 1) assess sidedress applications of N and K on corn grain yield in the MIdwest, 2) assess effect of N and K application on corn at three populations 3) evaluate K broadcast and sidedress by depth on grain yield, and 4) evaluate corn response to sidedress applications of N and K across a range of corn populations and assess types of K application. A secondary objective was to assess corn ear leaf K nutrition at multiple sites.

Methodology

Dryland research sites were established in grower fields near Sutherland, IA; Dodgeville, WI; Farmer City, IL, and an irrigated site at the Colorado State University ARDEK research farm near Wellington, CO in 2015, and Dodgeville, WI in 2016. Locations selected represent a range of soil types with a past crop yield history of >190 bu/ac^{-1}, and STK levels 140 – 250 ppm. An N and a K product sidedress study was established near Linden, WI, Calumet, IA, and Weedman, IL in 2015 and Sutherland, IA and Byron, IL in 2016.

Population NxK study. Corn populations of 26K, 32K, 38K, and 44K plants ac^{-1} were installed as main plots at three sites (IA, WI, and IL) and 34K, 41K and 48K plants ac-1 in CO in 2015. In 2016, the population study was conducted only at the Linden, WI site. Nitrogen was applied preplant based on a projected grain yield of 220 bu/ac^{-1}. Six subplot treatments were applied in 2015 at corn growth stage V4-V5 as a sidedress application consisting of:

check; N 40 lbs/ac^{-1}; 50 lbs ac^{-1} K; 40 lbs ac^{-1} of N + 50 lbs ac^{-1} K; VN rate and VN +50 lbs ac^{-1} K as a fluid using a spoke wheel injector system at a depth of 3 inches, 3 inches each side of the row. N source was urea and the K source was K acetate (Kac). Sub plot treatments were randomized within each population main plot, with six replications. For 2016, sidedress treatments consisted of N rates of 0, 50 lbs ac^{-1} and 50 lbs ac^{-1} +50 lbs K as K acetate with six replications. Soils were sampled preplant at five depth increments to 18 inches, along with in-season corn tissue samples at R1 to R2. Crop grain yield, harvest population, moisture, and test weight data were collected at harvest. Soils were evaluated for pH NO_3-N, M3-P, M3-K, CEC, Cl, using the Iowa State University moist soil test K method at Solum Laboratories, Ames, IA. Corn tissues were analyzed for N, P, K, Ca, Mg, S, Zn, Mn, Cu, B and nutrient ratios by Sure-Tech labs, Indianapolis IN. All sites were machine harvested.

K source study. An additional study was conducted in 2015 and 2016 to assess sidedress K application methods using a spoke wheel injector with treatments of: a check plot: (1) check treatment; (2) 50 lbs ac^{-1} KCl-K_2SO_4; (3) 100 lbs ac^{-1} KCL-K_2SO_4 (4) 50 lbs ac^{-1} K acetate; and (5) preplant top dress K_2SO_4 in 2016. Treatments were randomized complete block with six replications on sites with an established corn population of 32K plants ac^{-1}. Ear leaf tissue nutrients R1-R2, crop grain yield, harvest population, moisture, and test weight data were collected.

K observation study. In 2016, forty-eight observation sites were established in growers' fields across six states for the purpose of assessing the impact of soil K and crop nutrition on grain yield. Each site consisted of four check plots each 15 x 40 feet and data collected on soil fertility (pH, P, cations, SOM, CEC, Zn-DTPA), soil nutrient stratification, V2-V4 population, R1-R2 ear leaf nutrients, stalk nutrients, harvest population, and hand harvested for grain yield.

Results

Population NxK study. The 2015 plant population study showed optimum grain yields were obtained for planted populations between 32K and 38K plants per acre for three of the four locations (Figure 1). The Farmer City Illinois site was impacted by post emergence herbicide drift and, as a result, grain yields for the 44K planted population were reduced. The Wellington, CO site, which had planted populations of 34K, 41K and 48K plants per acre, had reduced yields associated with delayed early season irrigation and high spatial heterogeneity associated with previous treatments from research studies conducted in 2012. Population main plot CVs were 14%, 16%, and 21% respectively, with grain yields for the check plots ranging from 112 to 183 bu/ac for the 48K plants ac^{-1} population across the six plots. The Linden, WI site in 2016 showed yield optimum at a planted population 38K plants ac^{-1} at 255.4 bu ac^{-1}, which had a harvest ear population of 34,800 plants ac^{-1} (Figure 2).

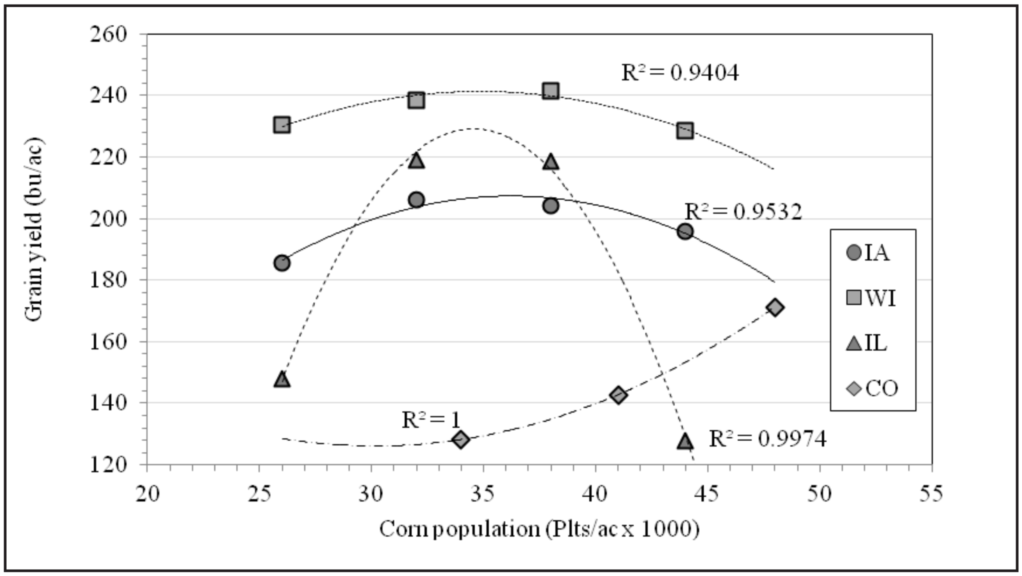

Figure 1. Impact of corn population on mean grain yield for four sites 2015.

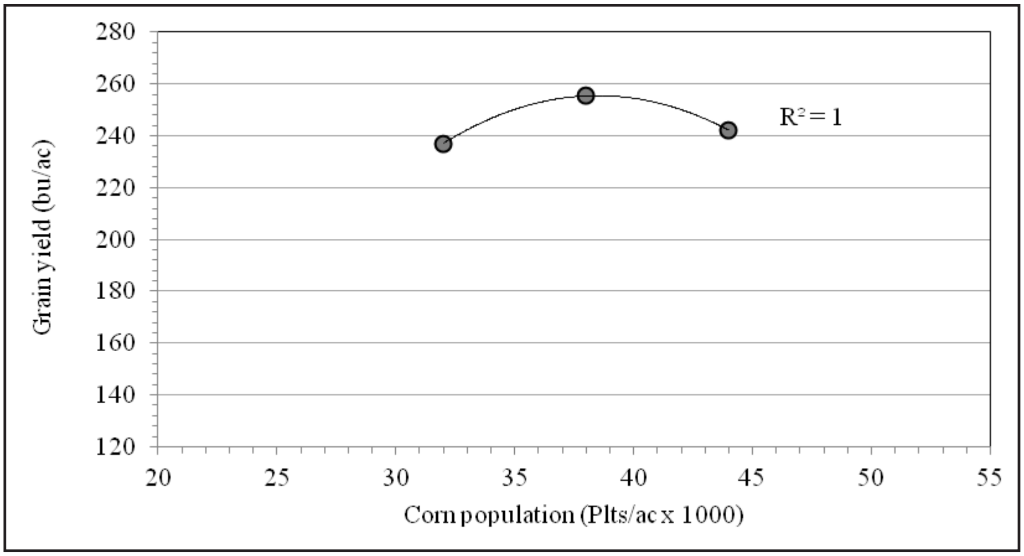

Figure 2. Impact of corn population on mean grain yield for Wisconsin site 2016

Observations of the 2015 corn population study showed higher plant populations resulted in an increasing percentage of plants not bearing ears. At the Sutherland, IA and Dodgevlle, WI sites, a planted population of 26K plants ac^{-1} resulted in a 1.7% to 2.0% reduction, respectively, across the two sites in plant-bearing ears, whereas the 44K plants ac^{-1} population resulted in 7.5% to 3.4% reduction in plant-bearing ears (Table 1). Similar results were noted for the Farmers City site, however crusting at emergence greatly reduced stand counts by V3.

Population in 2015 had no impact on grain yield for the 26K and 44K plant populations by sidedress N and K fertilizer applications at growth stage V3 to V4 at the Sutherland, IA

Table 6. Impact of population and side dress N and K source on grain yield for Linden, WI 2016.

Treatment [1,2,3]	Grain yield (bu ac^{-1})					
Plants ac^{-1} x 1000	32k		38k		44k	
Check	220.1	Delta Yield	234.6	Delta Yield	216.4	Delta Yield
50 N	240.8	20.7 *	266.7	32.1 *	247.2	30.8 *
50 N + 50 Kac	256.1	36.3 *	274.6	40.0 *	261.4	45.0 *

[1] Soil test K level 156 ppm.
[2] Fertilizer sources: Nitrogen urea; K acetate, rates lbs ac^{-1}.
[3] Mean results followed by (*) are significant at the 0.05 level from the check treatment.

Table 7. Impact of side dress N and K Source on corn grain yield for three Midwest sites 2015.

Treatment [1,2,3]	Grain Yield (bu ac^{-1})		
	Calumet, IA	Linden, WI	Weedman, IL
Check	194.1	219.0	183.2
50 N	217.1 *	229.6	200.2 *
50 Kac	205.9	230.6 *	187.4
50 N + 50 Kac	212.1 *	239.2 *	195.4 *
50 N + 50 KKCl	204.1	240.5 *	203.8 *

[1] Soil Test K levels by site: 192, 178 and 184 ppm, respectively.
[2] Fertilizer sources: nitrogen urea; K acetate and KCl, rates lbs ac^{-1}.
[3] Results followed by (*) are significant at the 0.10 level from the check treatment.

Table 9. Cluster comparisons of corn GS R1 ear leaf N, K, K:Mg, N:Mg and yield 2016.

Parameter	Low Leaf K Cluster [1,2,3]		High Leaf K Cluster	
	Mean	Stdev	Mean	Stdev
N %	2.51	0.26	2.83	0.18
K %	1.50*	0.22	2.76	0.35
Mg %	0.41*	0.05	0.17	0.04
N:K	1.71*	0.21	1.05	0.15
K:Mg	3.6*	0.7	17.1	3.8
N:Mg	6.0*	0.9	17.7	3.5
Yield (bu ac^{-1})	196.1	37.2	241.7	23.1

1 Ear leaf K, Mg and yield measurements based for 32 sites, 4 reps per site, across five states.
[2] Cluster analysis comparison of eight lowest and highest ear leaf K.
[3] Cluster means within a parameter followed by (*) are significant at the 0.05 level.

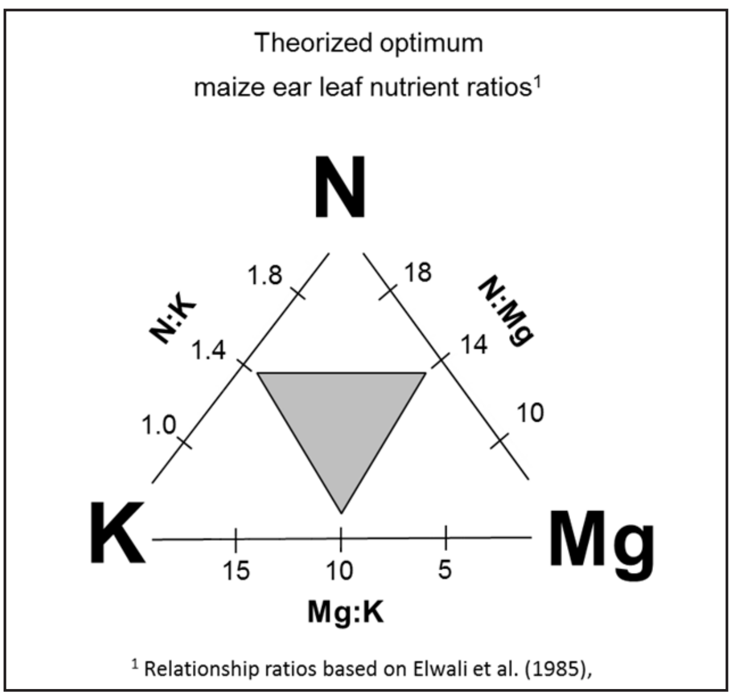

Figure 3. Diagram of theorized optimum maize ear leaf nutrient ratios based on Elwali et al (1985).

site (Table 2). Only the VN treatment showed significant increased grain yield for the 32K and 38K populations. There was no increase in grain yield over the check treatments with K or in combination with N. For the Sutherland, IA site it was noted that there was limited rainfall (<0.25 inches) for two weeks after the sidedress fertilizer treatment, which may have impacted crop uptake.

Sidedress N and K fertilizer applications at growth stage V3 to V4 at the Dodgeville, WI site had no statistically significant impact on grain yield within each of the four populations (Table 3). The same was true for the Farmer City, IL site (Table 4). It is worth noting that there was a strong trend showing N and K increasing yield for the 44K population, however it was masked by herbicide damage and subsequent variability.

"Further research needed to develop predictive models."

For the Wellington, CO site in 2015, sidedress N (50N) and NK (50N + 50K) fertilizer was applied at growth stage (GS) V4 to V5 (Table 5). The application of 50 N alone increased grain yields only for the 48K population treatment. The application of 50N + 50K significantly increased yield statistically across all populations and for the 48K population resulted in a grain yield increase of 77.9 bu ac^{-1} over the check plot.

The Linden, WI, the population study site in 2016 showed large increases in grain yield N and N+K over the check treatments for all three populations, with an average yield increase of 28 bu ac^{-1} sidedress N, and 36 bu ac-1 to N + K across all populations (Table 6). This site had a lower STK (154 ppm) and had ideal temperature and moisture conditions during corn CS V2-R1.

K source study. N and K source studies were conducted at three Midwestern sites in 2015 and one site in 2016. Results for 2015 show grain yield responses to N alone at two sites and to K alone at one site (Table 7). Fertilizer treatments of N

+ Kac or N + KKCl increased grain yield over the check at these sites, but only over N alone at the Linden, WI site, at an average of 10 bu ac^{-1}, non significantly. In 2016, the site in Byron, IL showed a 17.1 bu ac^{-1} response to top-dress 100 lbs ac^{-1} K_2SO_4 but no response to side-dress Kac at 50 or 100 lbs ac^{-1} applied at GS V3-V4 (Table 8). Yield response to K_2SO_4 may have been to either K or S at the site, although ear leaf analysis of the check plots showed S well within the sufficiency range, whereas leaf K was 1.08%.

K observation study. Beginning in 2011 and through 2014, corn leaf R1-R2 analysis data have been collected from research check plots at 76 sites across six Midwestern states where K fertility studies have been conducted. In 2016 this study was expanded to include 48 sites where data were collected on soil analysis, ear leaf nutrients, and stalk nutrients at maturity, population, and grain yield, based on four replications within grower fields across the Midwest from which 32 sites with complete data sets were selected. This datum set is extensive and full analysis is pending. Select data on leaf analysis and grain yield are discussed.

Using this database of 32 sites across 5 Midwestern states, cluster analysis comparisons contrasting eight sites with the lowest ear leaf K values and the eight with the highest were conducted (Table 9). Cluster results showed consistent mean leaf N value differences between clusters and, as expected, statistically significant differences in mean leaf K, along with elevated mean leaf Mg for the low K cluster. Large differences were noted in mean leaf N:K, K:Mg, and N:Mg ratios, with the low leaf K cluster having macro nutrient ratios outside corn DRIS optimum ranges as defined by Elwali, et al, 1985 (see Table 10). Most significant was that low ear leaf K clusters had significantly lower mean yield by 48.2 bu ac^{-1}. Further analysis of low vs. high ear leaf K clusters for 2011-2014 indicates that lower grain yields are associated with lower leaf K and that K:Mg ratios are consistently lower with K deficiencies in ear leaves (see Table 11). Over the five years, cluster analysis shows that sites with low ear leaf K and K:Mg ratios <6.0 have averaged 45.5 bu ac^{-1} lower yields relative to clusters which have K and K:Mg ratios falling within optimum ranges.

These results show a strong interaction of corn ear leaf K and Mg for corn at growth stage R1-R2, and when K deficiencies <1.9% occur there is a subsequent increase in ear-leaf Mg, resulting in lower K:Mg and N:Mg ratios. Based on DRIS ratios the relationship of N, K, and Mg is best shown in the theorized diagram (Figure 3) where the optimum ratios are achieved at the center of the triangle. With the onset of K deficiencies and subsequent increased Mg uptake, ratios of K:Mg and N:Mg shift to the lower right, and results in a consequent impact on grain yield. Although these results are preliminary, observation analysis of five years of field data shows a strong relationship between ear leaf K nutrition and grain yield.

Summing up

Results of the population study show optimum yields are obtained with planted populations of 32K-36K plants ac-1 based on 30 inch rows in the Midwest. Higher populations resulted in a reduced number of plants with ears and decreased yields. Grain yield response to population and side-dress N was site specific in 2015, with only a response to the VN treatment at the Sutherland, IA site and responses at the Wellington, CO site. 2016 results showed grain yield responses to both N and K at the Linden, WI site. Grain yield response to K source studies indicate site and product specific differences across four site years of research. Interactions with N were noted, and the average response to sidedressed K was 10 to 12 bu ac^{-1}.

Observational data analysis of corn ear leaf tissue nutrients, based on check plots established in grower fields from 2011 to 2016, indicate leaf K levels <1.9% are indicative of lower yields and that, with K deficiencies, corn leaves showed increased Mg accumulations resulting in lower K:Mg ratios and substantially lower grain yields. Establishing N, K, Mg DRIS ratio norms is an effective tool in diagnosing corn K deficiencies and addressing K fertility management of corn. Further research is needed to develop predictive models of corn K nutrition based on soil test methods and weather variables.

Table 11. Cluster comparisons of corn GS R1 ear leaf K, K:Mg and yield over five years, 112 sites.

Year	Low K Cluster [123]		High K Cluster		Delta Yield
	K (%)	K:Mg	K (%)	K:Mg	(bu/ac)
2011	1.77*	5.9*	2.64	11.1	40.9*
2012	1.52*	3.2	1.91	6.7	58.1*
2013	1.67	3.0*	1.95	8.3	34.5
2014	1.60*	4.7*	2.17	10.1	48.2*
2015	-	-	-	-	-
2016	1.50*	3.6*	2.93	14.3	45.6

[1] Ear leaf K, Mg and yield measurements for 112 sites, 4-8 reps per site, across seven states.
[2] Cluster analysis of five lowest and highest ear leaf K, 16 to 32 sites. Number of sites per year, yearly dependent.
[3] Cluster means within a year followed by (*) are significant at the 0.05 level.

Table 10. Corn leaf nutrient DRIS norms.

Nutrient Ratio 1	Average	Stdev
N:P	9.03	2.14
N:K	1.46	0.43
N:Mg	14.1	4.1
N:S	11.9	2.2
K:Mg	9.6	3.6

[1] Ratios based on research of Elwali et al. 1985.

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