EVALUATION OF POLYHALITE AS A SOURCE OF POTASSIUM AND SULFUR FOR A CORN-SOYBEAN ROTATION IN MINNESOTA

Apurba K. Sutradhar, Daniel E. Kaiser, and Carl J. Rosen
University of Minnesota – Saint Paul, MN
dekaiser@umn.edu

ABSTRACT

Polyhalite contains K, S, Mg, and Ca which could be used as a source of nutrients for crops in Minnesota. The objective of this research was to determine if polyhalite can utilized within for a two-year corn (*Zea mays* L.)-soybean [*Glycine max* (L.) Merr.] rotation. Field studies were established at two locations in Minnesota with the soil test K of <120 ppm (0-6 inch sample extracted with 1M NH_4OAC) and where a response to S was expected. Treatments were polyhalite, muriate of potash [MOP (KCl)], and a mixture of polyhalite and MOP blend applied at four application rates. Corn was grown at each site in 2015 and then rotated to soybean in 2016. Corn ear leaf K and S concentration was increased by K and S application. Soybean trifoliate K concentration was not affected by fertilizer sources but increased with higher rates of fertilizer at Saint Charles. Trifoliate S concentration increased at higher rate of S only when fertilizers containing S were applied at Saint Charles. Corn grain yield was increased by S at both locations. When there was a response in corn grain yield there was no difference in based on whether the source of fertilizer was polyhalite or KCl or polyhalite or gypsum. The results indicated that, depending on product cost, polyhalite can be substituted for KCl or gypsum to supply K and S to crops in Minnesota. The data indicates a better chance of a positive economic return when polyhalite was applied to supply S for corn.

INTRODUCTION

Polihalite [$K_2MgCa_2(SO_4)_4.2H_2O$] contains four essential plant nutrients (14% K, 19% S, 6% Mg, and 12% Ca) and can be used as fertilizer for corn and soybean production to replace the need for separate application of KCl and S. The material can be a good option for farmers in soils with high soil test Cl. Since the fertilizer does not contain Cl, application of this fertilizer can potentially reduce the risk of Cl toxicity for susceptible crops.

Most Minnesota soils are well supplied with S. However, research has shown application of S can benefit corn producers when grown on sandy soil (Rehm, 2005). Recent research in Iowa and Minnesota has shown crops responded to S application in fine-textured soil that are eroded (Sawyer and Barker, 2002; Rehm 2005; Sawyer et al., 2009, Kim et al., 2013). Research trials in Minnesota have shown application of S increased corn grain yield when soil organic matter in the top six inches is less than 4% (Kaiser et al., 2010).

The use of K fertilizer can produce profitable increases in corn and soybean yield. Potash fertilizer is suggested for corn if the soil test for K is less than 160 ppm. The amount of K fertilizer to be applied in Minnesota for corn varies based on soil test value and expected yield. For low soil test K (41-80 ppm) and an expected yield of 200 bushels per acre, 155 lb K per acre is suggested as broadcast (Kaiser et al., 2011). Similar to corn, the amount of K fertilizer needed to apply for soybean vary based on soil test K and yield goal. A 60 lb K per acre is recommended for 50 bushels soybean grain yield when soil test K range from 41-80 ppm (Kaiser et al., 2011).

Polyhalite can be used as a substitute for K and S supplement to a corn-soybean rotation system. Use of polyhalite can help offset the need of multiple sources of fertilizer. The research objective of this work was to evaluate the use of polyhalite alone and in a blend within a 2-year corn-soybean rotation and to determine if K or S in polyhalite was responsible for increase corn and soybean plant tissue nutrient concentration and grain yield.

RESEARCH METHODS

Studies were established at two locations (Saint Charles and Staples) in Minnesota in 2015 (Table 1). The studies were two-year corn-soybean rotation system in which corn was planted in 2015 and rotated to soybean in the 2016 growing season. Prior to treatment application in 2015, soil samples were collected from each plot at the 0-6 inch depth. Soils were analyzed using standard procedures recommended for the North Central region. Preliminary soil test results are presented in Table 1.

Treatments consisted of varying rates of K and S applied using a factorial design replicated four times. Two factors were studied. Factor 1 consisted of K and S sources and factor 2 consisted of rates (Table 2). Fertilizer sources were polyhalite, muriate of potash (MOP), gypsum, and a blend of MOP and polyhalite. All fertilizer sources were broadcast applied and incorporated prior to planting. The rate variable (Factor 2) was based on matching the rate of K or S applied in the polyhalite or polyhalite/MOP blend with MOP or gypsum. Additional N and K fertilizer was applied to plots at non-limiting rates.

At Saint Charles, the corn variety Pioneer P0157 AM1 was planted on May 1, 2015 at the rate of 35,500 seeds per acre. At Staples, Wensman W80841VT2RIB was planted at the rate of 35,000 seeds per acre. Ear leaf samples were sampled when corn plants were at approximately the R2 growth stage. Twenty leaves opposite and below the ear were sampled within each plot. Corn grain yield samples were collected by hand harvesting 20 feet from the center of the middle two rows in each plot. Grain yield is reported at 15.5% moisture content.

The soybean variety Pioneer P22T69 was planted at Saint Charles on Apr. 28, 2016 at the rate of 150,000 seeds per acre. At Staples, Croplan R2T0601 was planted on May 18, 2016 at the rate of 140,000 seeds per acre. Twenty soybean trifoliate samples (uppermost fully developed trifoliate including the petiole) were sampled when soybean plants were at approximately R2 growth stage. All tissue samples were dried, ground, and analyzed by ICP for K, S, Mg, and Ca concentration.

Statistical analysis was conducted using PROC GLIMMIX in SAS (SAS Institute, 2011). Analysis was conducted using a factorial design. Factor 1 consisted of fertilizer treatment (gypsum, MOP, polyhalite, and MOP/polyhalite). Factor 2 consisted of a rate variable. The rate of product or nutrient was not consistent across all fertilizer treatments but the analysis of the factorial design allowed for the determination of differences in the effect of application rate among the fertilizer sources. Spatial analysis was conducted using the plot residuals which improved treatment significance at both locations (Gbur et al., 2012). Preliminary soil test values were also used as covariates in the analysis but were shown to be of little benefit. Significant interactions between fertilizer source and rate were investigated using the SLICE option in the LSMEANS statement to determine the effect of rate within fertilizer source. All means presented in this report are means adjusted for spatial variability (least squares means).

Relationships between two variables were investigated using PROC REG in SAS (SAS Institute, 2011).

RESULTS AND DISCUSSION

Initial soil test results collected prior to corn planting in 2015 are listed in Table 1. Soil P tested low at Saint Charles and very high at Staples (Kaiser 2011). Soil K tested low at both locations. Soil organic matter concentration was within the range where a S deficiency is expected (Kaiser et al., 2010). Sulfur soil tests are not suggested for use on medium and fine-textured soils in Minnesota.

Tissue nutrient concentration at R2 growth stage

Fertilizer source, rate, and source by rate interaction were significant for corn ear leaf K concentration at both Saint Charles and Staples locations (Table 3 and 4). Preliminary analysis indicated that K fertilizer in the MOP and polyhalite increased ear leaf K concentration at Saint Charles (Figure 1a). In contrast, there was a negative effect on ear leaf K concentration detected when fertilizer K and S were applied at higher rate at Staples. This site was characterized by visible S deficiency. A negative rate effect on ear leaf K concentration at Staples (figure 1b) was likely due to K dilution in the plant tissue due to increased plant mass when S was applied.

Corn ear leaf S concentration was affected by fertilizer source and rate at both locations (Table 3 and 4). At Saint Charles, interaction between fertilizer source and rate was not significant while the interaction was significant at Staples. At Saint Charles, polyhalite had the greater ear leaf S concentration followed by gypsum and MOP/polyhalite blend. The MOP treatment had the least concentration of S in the ear leaf tissue which made sense as no S was applied with this treatment. The lack of an interaction between source and rate also indicates that a difference existed among the rates of MOP applied without S. Interaction of fertilizer source and rate was significant at Staples. Fertilizer rates within the fertilizer sources were significant except MOP indicating that increased ear leaf S concentration was due to the effect of S (Figure 2). Similar to Saint Charles, ear leaf S concentration was greatest with the polyhalite only treatment which applied the greatest total S, on average, of all the sources.

Soybean trifoliate K concentration was not affected by fertilizer source at any location (Table 3 and 4). However, fertilizer rate slightly increase trifoliate K concentration at Saint Charles while fertilizer rates did not affect trifoliate K concentration at Staples. No significant interaction between fertilizer source and rate was evident. Rate analysis for Saint Charles indicated that high rate of K and S did not result in greater trifoliate K concentration.

Fertilizer source, rate, and their interaction significantly affected soybean trifoliate S concentration at Saint Charles (Table 3) but no effect was significant at Staples (Table 4). Trifoliate S concentration was increased by gypsum and polyhalite at Saint Charles (Figure 3). Since no fertilizer was applied between the corn and soybean crop an increase in trifoliate S concentration would be due to S carried over from the previous year’s fertilizer application. There was no increase in trifoliate S concentration with increasing MOP rate at Saint Charles.

Tissue Ca and Mg concentrations were regressed with tissue K concentration for each of the crop across locations (Figure 4). Corn ear leaf Ca concentration increased linearly with the increase of ear-leaf K concentration. On the other hand, a quadratic relationship was detected between soybean trifoliate Ca and K concentrations. The increase in trifoliate Ca concentration was very small and declined at trifoliate K concentration of 2.5%. In both cases, lower R^2 values indicated that these models poorly explain the variation in tissue Ca concentration in relation to tissue K concentration. In contrast, tissue Mg concentration was highly correlated with tissue K concentration. Ear-leaf and trifoliate Mg concentration declined sharply in a linear fashion. A negative impact of fertilizer K on plant Mg concentration is not unexpected since high K in the plant tends to result in low Mg.

Fertilizer source and rate effects on grain yield

Corn grain yield was not affected by fertilizer sources at Saint Charles in 2015 but grain yield increased with the increased fertilizer application rate (Table 3). There was no significant source by rate interaction detected at Saint Charles. A significant response to fertilizer rate without a response to source, or an interaction between source and rate, makes it difficult to determine what nutrient may have impacted yield the most at Saint Charles. Plant tissue could be used to separate out the effect of either nutrient. However, both K and S were increased at Saint Charles. Evaluation of the relative levels of K and S in the ear leaf tissue indicates that both would be considered deficient by suggestions given by Bryson et al. (2014). The relative difference in S in the ear leaf tissue among the sources is a good indicator that S may have had a greater impact on yield potential at Saint Charles than K. The effect of K cannot be ruled out due to the soil test K average for the Saint Charles location.

At Staples, corn grain yield was affected by both fertilizer sources and rate (Table 4). A significant source by rate interaction was also detected. Examination of yield data for the interaction (Figure 5) shows a general increase in corn grain yield when S was applied relative to the MOP treatment where K was applied without S. This means grain yield was impacted by only S application from all sources. A response to S is not surprising as there were clear visible S deficiency symptoms at this location. The Staples location is irrigated but the amount of S from the irrigation water has been negligible and is not expected to be sufficient for all of the S needs of corn (data not shown).

Soil test S results indicated that S was not limiting for corn according to University of Minnesota interpretations (Table 1). However, a yield response to applied S at Staples and possibly at Saint Charles supports the agreement that soil test S cannot be used to predict S deficiency in soil except for sandy soil (Kim et al., 2013). Soil K tests at both sites were low enough where a response to K would have been likely. Other research at the same locations studying only K have not shown consistent increases in yield due to K application at similar soil test values.

CONCLUSIONS

The data presented in this report suggest that polyhalite can be an effective source of K or S for corn and soybean. Tissue K and S concentration increased when K or S were applied regardless of source. Lack of consistent increases in grain yield indicated that increased tissue K and S concentration was due to luxury consumption of the nutrients and not of a deficiency of one or both at each location. The treatments applied made it difficult to determine which nutrient were more important for increasing grain yield. However, there is evidence that S and not K was more limiting at both locations. Due to the higher concentration of S in polyhalite, application based on S requirement of corn may be more economical due to a greater response potential in corn.

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TABLES AND FIGURES

Table 1. Site soil test P, K, pH, soil organic matter (SOM), Ca, Mg, and SO_4-S from composite samples (10) cores taken before treatment application.

Site	P†	K	pH	SOM	Ca	Mg	SO_4-S
	-----ppm-----			-%-	-----ppm-----		
Saint Charles	9	71	6.9	0.27	1504	300	5
Staples	33	86	7.0	0.23	1411	122	5

† P, Bray-P1; K, ammonium acetate; pH, 1:1 soil to water; SOM, soil organic matter by dry combustion; Ca and Mg by ammonium acetate; SO_4-S, sulfate-S by mono-calcium phosphate.

Table 2. Fertilizer treatments and nutrients applied for the two-year corn-soybean study in Minnesota. All fertilizer applied prior to corn planting in 2015. Fertilizers were not applied in 2016 before soybean planting.

Fertilizer Source	Rate Code	K_2O applied	S applied	Polyhalite	MOP	Gypsum
		--------------------------lb/acre--------------------------				
Gypsum	1	120	0	0	201	0
	2	120	13	0	201	71
	3	120	28	0	201	144
	4	120	41	0	201	376
MOP	1	0	0	0	0	0
	2	40	0	0	67	0
	3	80	0	0	134	0
	4	120	0	0	201	0
Polyhalite	1	0	0	0	0	0
	2	40	54	287	0	0
	3	80	109	574	0	0
	4	120	163	861	0	0
Polyhalite/MOP	1	0	0	0	0	0
	2	40	13	71	50	0
	3	80	28	144	101	0
	4	120	41	215	151	0

Table 3. Summary of corn grain yield and concentration of K, and S in a composite sample consisting of ten corn ear leaves and twenty soybean trifoliate samples collected at R2 at Saint Charles. Data summarized by main effect of four fertilizer sources applied at four rates. Numbers followed by different lower case letters are significantly different at $P \leq 0.10$.

Sources of Variation	Corn, 2015			Soybean, 2016	
	Ear Leaf			Trifoliate	
	K	S	Yield	K	S
	%	%	bu./acre	%	%
			Main Effects		
Fert. Source					
Gypsum	1.5 a	1.4 b	199	1.8	0.26 a
MOP	1.4 b	1.2 c	195	1.7	0.24 b
Poly	1.4 b	1.5 a	203	1.6	0.26 a
Poly/MOP	1.4 b	1.4 b	201	1.7	0.25 ab
Fert. Rate					
1	1.3 c	1.3 c	191 b	1.5 b	0.25 b
2	1.3 c	1.4 b	199 ab	1.7 ab	0.25 b
3	1.5 b	1.5 a	206 a	1.8 a	0.25 b
4	1.6 a	1.4 b	204 a	1.8 a	0.26 a
Statistics	---------------------------------*P*>F---------------------------------				
Source	0.08	<0.01	0.33	0.28	<0.01
Rate	<0.01	<0.01	0.01	<0.01	<0.01
Source x Rate	<0.01	0.37	0.26	0.30	<0.01

Table 4. Summary of concentration of K, and S in a composite sample consisting of ten corn ear leaves and twenty soybean trifoliate samples collected at R2 at Staples. Data summarized by main effects of four fertilizer sources applied at four rates. Numbers followed by different lower case letters are significantly different at $P \leq 0.10$.

Sources of Variation	Corn, 2015			Staples	
	Ear Leaf			Trifoliate	
	K	S	Yield	K	S
	%	%	Bu./acre	%	%
			Main Effects		
Fert. Source					
Gypsum	2.1 b	1.8 b	206 a	2.5	0.24
MOP	2.2 a	1.6 c	177 b	2.5	0.25
Poly	2.0 b	2.0 a	199 a	2.5	0.25
Poly/MOP	1.9 c	1.9 ab	204 a	2.5	0.25
Fert. Rate					
1	2.1 a	1.7 b	182 b	2.5	0.25
2	2.0 b	1.9 a	196 a	2.6	0.25
3	2.0 b	1.8 a	204 a	2.6	0.25
4	2.0 b	1.9 a	204 a	2.5	0.25
Statistics	-----------------------------------	------------	*P*>F	------------	-----------------------------------
Source	<0.01	<0.01	<0.01	0.79	0.23
Rate	<0.01	<0.01	<0.01	0.60	0.86
Source x Rate	<0.01	<0.01	<0.01	0.81	0.40

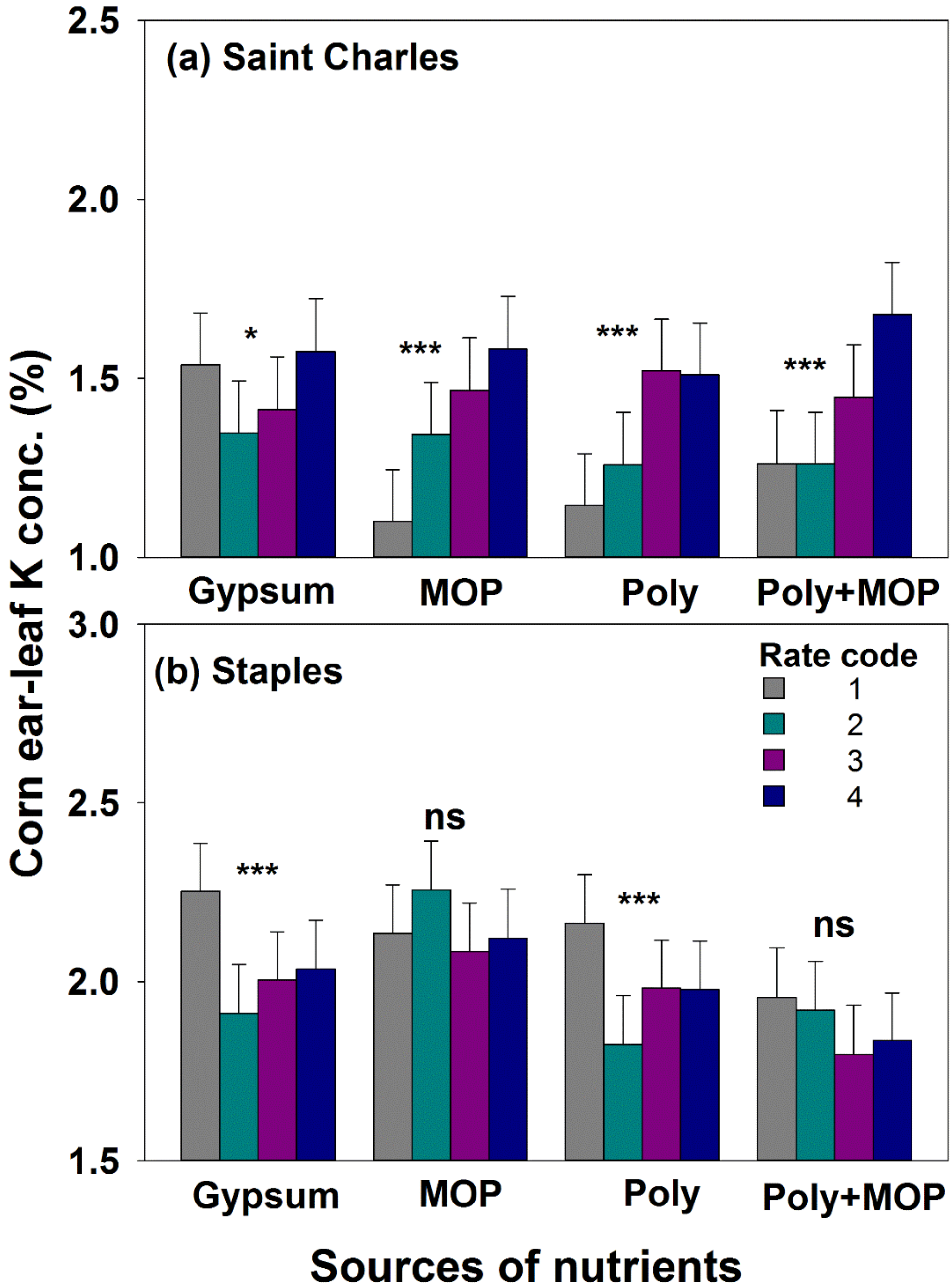

Figure 1. Analysis of corn ear leaf K concentration at R2 growth stage by fertilizer source at each location. Error bars indicate standard error of the mean. Asterisks above bars indicate the significance levels of fertilizer rates within a fertilizer source. ("*" and "***" indicate rates are significant at P <0.1 and P <0.01 levels of probability, ns indicates rates are not significant).

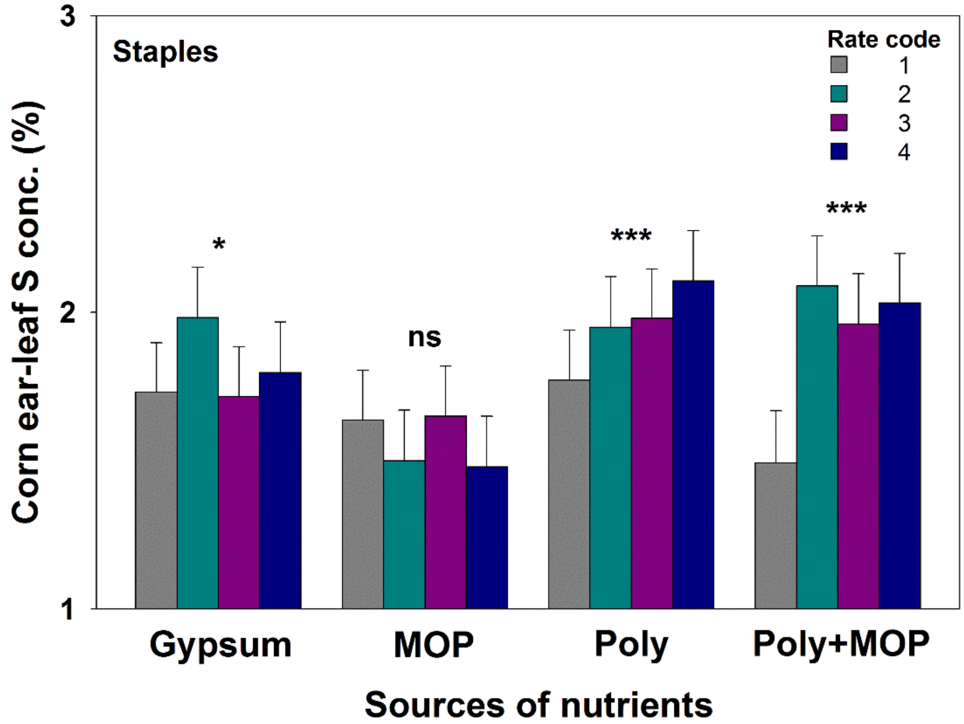

Figure 2. Analysis of corn ear leaf S concentration at R2 growth stage by fertilizer source at Staples. Error bars indicate standard error of the mean. Asterisks above bars indicate the significance levels of fertilizer rates within a fertilizer source. (“*” and “***” indicate rates are significant at P <0.1 and P <0.01 levels of probability, ns indicates rates are not significant).

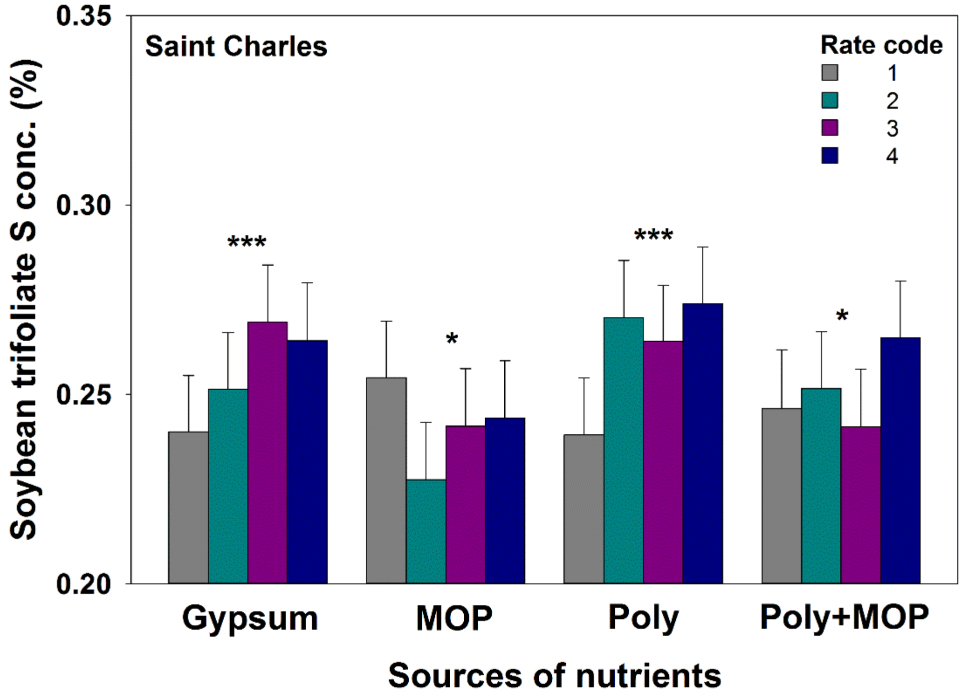

Figure 3. Analysis of soybean trifoliate S concentration at R2 growth stage by fertilizer sources at Saint Charles. Error bars indicate standard error of the mean. Asterisks above bars indicate the significance levels of fertilizer rates within a fertilizer source. ("*" and "***" indicate rates are significant at P <0.1 and P <0.01 levels of probability, ns indicates rates are not significant).

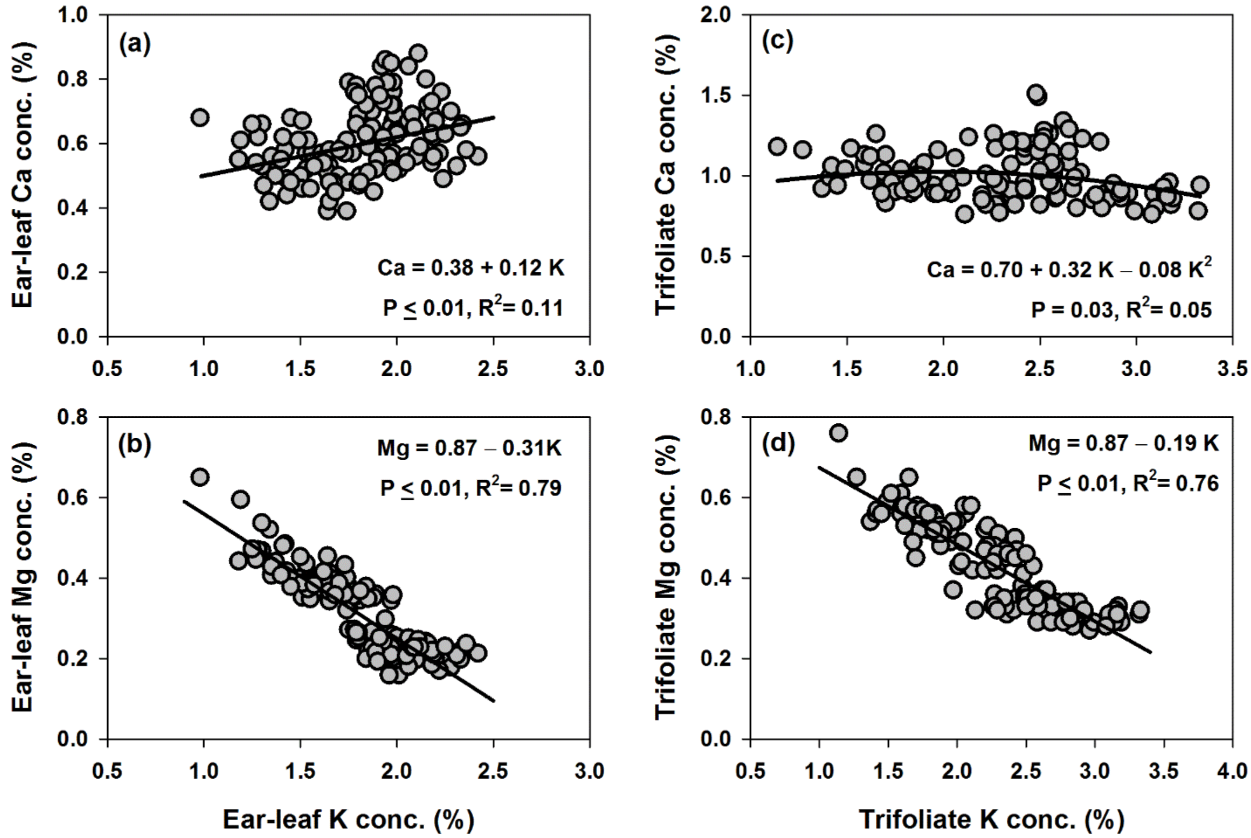

Figure 4. Relationships of plant tissue Ca and Mg concentrations with tissue K concentration in corn ear-leaf and soybean trifoliate at the R2 growth stage.

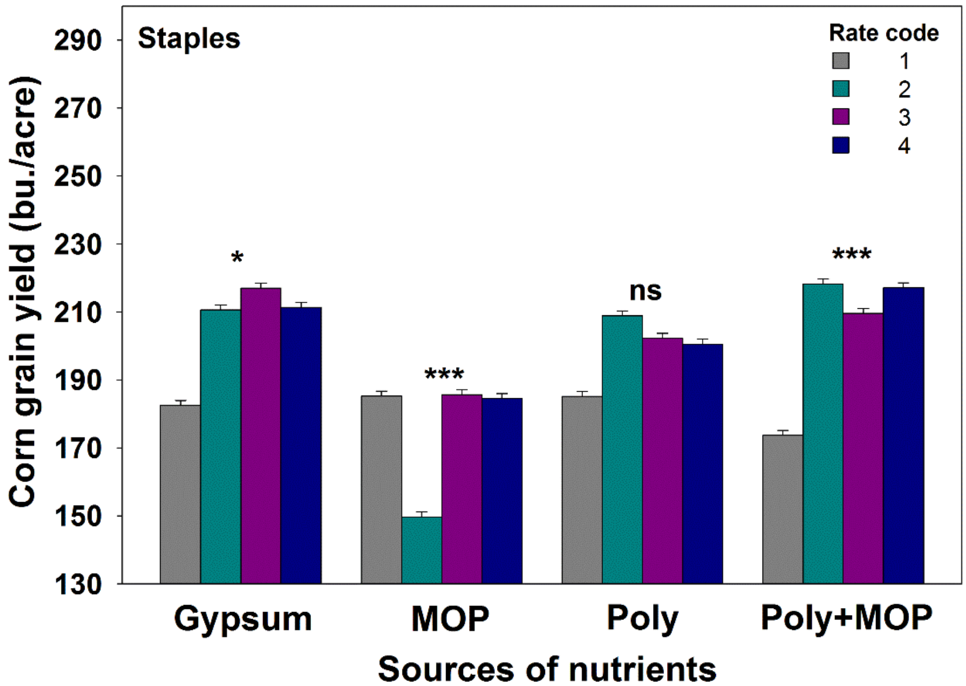

Figure 5. Analysis of corn grain yield by fertilizer source at Staples. Error bars indicate standard error of the mean. Asterisks above bars indicate the significance levels of fertilizer rates within a fertilizer source. ("*" and "***" indicate rates are significant at P <0.1 and P <0.01 levels of probability, ns indicates rates are not significant).

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(785) 532-7213
ruizdiaz@ksu.edu

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