Evaluation of Post-Emergence Fluid Potassium Fertilizer Application for Corn Production

COMBINATION OF FINAL REPORTS TO

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Antonio P. Mallarino, Professor, Iowa State University

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Justification for the Study and Objectives

Iowa State University (ISU) research since the middle 1990s has been evaluating the corn and soybean response to P and K fertilizer placement methods. Other than starter research using liquid fertilizers, the placement methods for the primary P or K application have used granulated fertilizers broadcast or deep-banded before planting the crops and banding with the planter 2 inches besides and below the seeds. Results have shown small or no differences between broadcast and planter-band methods for P and K in corn managed with tillage, no-till, strip-till, or ridge-till. Deep K deep banding (5 to 6 inches deep) always was better than other placement methods with ridge-till and to a lesser degree and frequency with no-till or strip-till. Research that compared fall or spring application of P and K found no differences.

Growers were asking if they could reduce preplant K fertilizer rates by sidedressing K after emergence at about the same time N is sidedressed. Research has shown that sufficient P should be available very early for cell division and sink development, but this is not nearly the case for K. This explains frequent corn response to starter P, sometimes even with soil-test P optimum or higher, but not for K unless soil-test K (STK) is very deficient. Therefore, new research was deemed needed to see if K application when corn begins its high rate of uptake and demand at about the V5 to V6 growth stage could increase yield even when pre-plant fertilization or STK levels seem adequate.

The objectives of the project were to evaluate how sidedressed injected liquid K fertilizer interacts with pre-plant broadcast K fertilization, the STK level, and the yield level at affecting corn tissue K concentration and grain yield. Irrigation is rare in Iowa and the upper 2 to 3 inches of soil usually are dry during early summer and K is much less mobile than nitrate. Therefore, liquid fertilizer and an injection placement method were chosen because these are likely to be more efficient than surface application of dry or liquid fertilizers for post-emergence K fertilization without irrigation.

Overview of Procedures

Twelve field trials with corn were conducted in Iowa. In 2017, six trials were at the central (Site 1), southern (Sites 2 and 3), northeast (Site 4), northern (Site 5), and southeast (Site 6) ISU research farms. In 2018, six new corn trials were at the southern (Sites 7 and 8), northeast (Site 9), northern (Site 10), southeast (Site 11), and southwest (Site 12) ISU research farms. The previous crop was soybean for all trials. With the only exception of Site 12, which was managed with no-tillage, the tillage of all other trials consisted of spring light disking or field cultivation. Table 1 shows the soil series and selected basic soil properties measured on a composite sample taken from the trial areas.

Table 1. Soil series and selected soil properties of the twelve sites.

Year	Site	Soil Series	pH	OM†	Extractable Cations Ca	Mg	Na	CEC‡	Texture
				%	-----------	ppm	--------		
2017	1	Clarion	5.31	3.76	1867	298	8	20.0	Loam
	2	Haig	6.30	4.01	2602	333	16	18.0	Silty clay loam
	3	Haig	6.30	3.60	2400	310	13	17.4	Silty clay loam
	4	Kenyon	5.76	2.32	1715	258	10	13.4	Loam
	5	Webster	6.74	4.06	4752	514	13	28.4	Clay loam
	6	Taintor	5.60	4.32	2501	512	10	24.4	Silty clay loam
2018	7	Grundy	6.74	4.34	2920	324	15	18.0	Silty clay loam
	8	Grundy	6.90	3.90	2850	290	14	17.1	Silty clay loam
	9	Floyd	6.04	4.73	2653	409	11	20.4	Clay loam
	10	Webster	6.15	4.61	3802	621	19	27.4	Clay loam
	11	Mahaska	5.94	4.27	2696	534	12	21.3	Silty clay loam
	12	Exira	6.06	2.77	2752	586	11	20.3	Silty clay loam

† OM, organic matter; ‡ CEC, cation exchange capacity.

The K treatments were applied to plots of a previous study which had plots and STK levels suitable for the objectives of this new study. Each trial had four blocks (replications) with five plots measuring 40 foot wide by 50 to 60 foot long depending on the research farm. Four plots of each block had deficient and uniform STK at each site, which across sites was Very Low, Low, or Optimum (for which a removal-based K rate is recommended) according to ISU soil-test interpretation categories. One plot tested High or Very High, for which no K fertilization is recommended other than a small starter rate for the High category in a few some conditions. Table 2 shows the initial STK values for all trials.

Table 2. Initial soil-test K for low- and high-testing areas of six trials in 2017.

		Low-Testing Plots				High-Testing Plots	
		Dry Sample Test		Moist Sample Test		Dry Sample Test	
Year	Site	Value†	Category‡	Test Value	Category	Test Value	Category
		ppm		ppm		ppm	
2017	1	104	VL	48	VL	221	High
	2	125	Low	53	Low	223	High
	3	120	VL-Low	51	VL-Low	210	High
	4	149	Low	58	Low	280	VH
	5	171	Optimum	77	Low	246	VH
	6	171	Optimum	68	Low	256	VH
2018	7	169	Optimum	68	Low	231	High
	8	166	Optimum	60	Low	211	High
	9	105	VL	46	VL	274	VH
	10	155	Low	46	VL	220	High
	11	180	Optimum	86	Low-Optimum	367	VH
	12	193	Optimum	60	Low	273	VH

† All test results are averages for ammonium-acetate and Mehlich-3 methods. ‡ Iowa state University interpretation categories for testing of dried or field-moist samples (VL, Very Low; VH, Very High); from extension publication PM 1688 (Mallarino et al., 2013).

The crop and soil management histories for each trial had been similar except for K fertilization. The four low-testing plots had received no K application during the last five to seven years. The high-testing plots had received annual rates of 90 to 120 lb K_2O/acre during the last four to six years and annual rates of 180 to 240 lb K_2O/acre during the previous four to six years.

Ten K treatments were evaluated at each trial arranged in a split-plot randomized complete-block design with four replications. Five preplant K treatments were in large plots and two K sidedress treatments were in subplots. Four preplant treatments were 0, 45, 90, or 135 lb K_2O/acre randomized to the four low-testing plots and no K application to the high-testing plots. The preplant fertilizer was granulated potash fertilizer (KCl, 0-0-62) broadcasted in the spring and before tillage for the subplots eleven trials managed with tillage. The two sidedress K treatments were 0 or 45 lb K_2O/acre, which consisted of liquid K fertilizer (potassium acetate, 0-0-24) injected to a depth of 3-4 inches at the center of corn each inter-row at the V5-V6 growth stage. Non-limiting uniform rates of N, P, and S fertilizers were applied across all plots of all trials.

Corn hybrids (Pioneer brand) adapted to the different regions were used. In 2017, the hybrids were P1197AMXT at both the central and southeast farms, P0157AMX at both the northern and northeast research farms, and P1157AM at the southern farm. In 2018, the hybrids were P0157AMX at both the northern and northeast farms, P0574AMXT at the southeast farm, and P1197AMXT at both the southern and southwest farms. Corn was planted using a 30-inch row spacing the target seeding rate was 32,000 to 36,000 plants per acre across the sites.

In 2017, corn planting and liquid K fertilizer sidedressing dates were April 26 and June 6 at the central Iowa farm (Site 1), April 25 and June 14 at the southern farm (Sites 2 and 3), April 25 and June 17 at the northeast farm (Site 4), May 7 and June 9 at the northern farm (Site 5), and May 9 and June 12 at the southeast farm (Site 6). In 2018, corn planting and liquid K fertilizer sidedress dates were April 27 and May 30 at the southern farm (Sites 7 and 8), April 30 and June 1 at the northeast farm (Site 9), May 18 and June 18 at the northern farm (Site 10), May 8 and June 4 at the southeast farm (Site 11), and May 1 and May 31 at the southwest farm (Site 12).

Corn ear-leaf blades were sampled at the R1 growth stage (silking) to measure tissue total K concentration. Grain yield was harvested with plot combines, samples were taken to be analyzed for K concentration and K removal, and yield was expressed at a 15% moisture.

Results for 2017

Figure 1 shows the grain yield results from six trials conducted in 2017. As expected, the corn yield level varied greatly across the six sites. The highest observed yield treatment means (average across four replications) were 237, 152, 146, 228, 259, and 234 bu/acre for Sites 1, 2, 3, 4, 5, and 6, respectively. Yield at Sites 1, 4, 5, and 6 were about the average for recent years, but were very low at Sites 2 and 3 (the two southern Iowa sites). Slightly lower yield was expected for these two sites because of slightly lower soil yield potential, but such a very low yield is explained by severe drought from late April until late September, a period that included early corn growth, silking and pollination, and grain filling stages. Slightly less than normal rainfall from early August to September limited yield slightly at Site 4.

Statistical analyses (not shown) and fitted response models in Fig. 1 confirmed a yield increase from broadcast preplant K fertilization at Sites 1, 4, 5, and 6 but not at the drought-affected Sites 2 and 3. Small to large yield increases from preplant K were expected at all sites because STK of the trials area to which preplant K was applied was Very Low to Optimum by the dry K test and Very Low to Low by the moist test (Table 2). The probability of corn yield responses to K fertilization for categories Very Low, Low, Optimum, High, and Very High are 80, 60, 25, 5 and 1 percent, respectively (Mallarino et al., 2013).

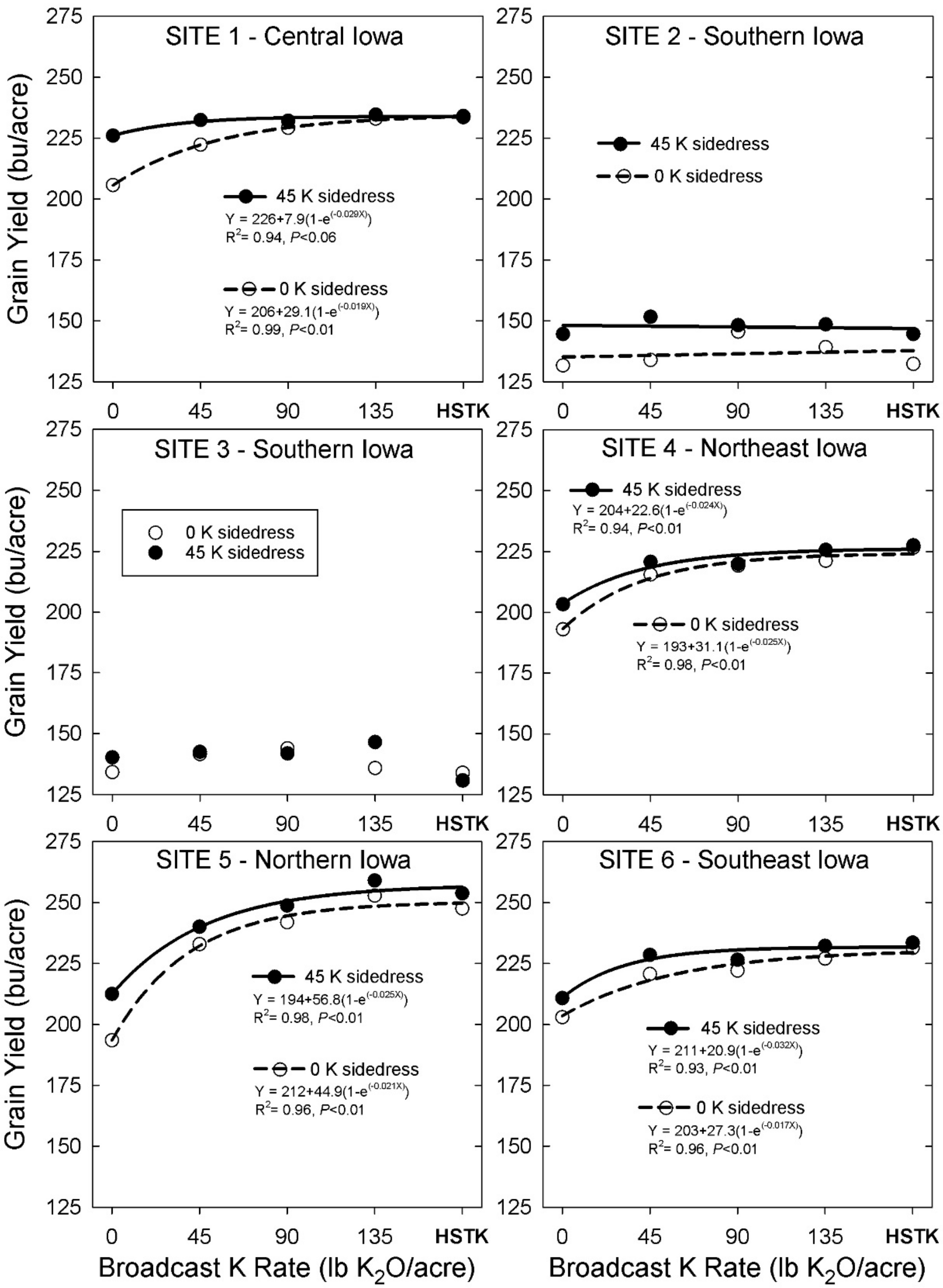

Fig. 1. Corn grain yield response to preplant and sidedressed K fertilization at six sites in 2017. HSTK, high-testing preplant treatment.

At the four responsive sites, yield increases were the largest at Site 5 (40 bu/acre, with STK Low and Optimum by the moist and dry testing procedures), intermediate at Site 4 (23 bu/acre with STK Low by both testing procedures), and lowest (17 or 18 bu/acre) at Sites 1 (STK Very Low by both testing procedures) and 6 (with STK Low and Optimum by the moist and dry testing procedures, respectively). Preplant K rates of 90 or 135 lb K_2O/acre maximized yield to the same level observed for the high-testing treatment, although at Sites 4 and 6 the additional increase over the 45-lb rate was small. The recommended K rates for corn in Iowa are 130 and 90 lb K_2O/acre for the categories Very Low and Low, respectively, and a removal-based rate for the Optimum category (Mallarino et al., 2013).

The sidedressed K fertilizer increased yield at most sites, with the only exception of Site 3, which was one of the southern Iowa drought-affected sites. At the responsive sites, the yield increase from sidedressed K was the largest for the control that received no preplant K although was not sufficient to increase yield to the maximum plateau yield except for Site 2. A yield response to sidedressed K at Site 2 for all preplant rates but not at Site 3 cannot be explained satisfactorily because the initial STK was slightly lower at Site 3 and soil series, basic soil properties (Table 1), yield levels, lack of response to preplant K, and rainfall (not shown) were similar for both sites. The small additional yield increases from sidedressed K for preplant rates of 45 and 90 lb K_2O/acre were sufficient to attain the same maximum yield observed for the 135-lb preplant rate and the high-testing soil treatment at most sites. The only exception was at Site 5 for reasons not understood. On average across the five yield responsive sites, the 45-lb preplant rate without sidedressed K increased yield by 20 bu/acre over the non-fertilized control whereas the similar 45-lb sidedressed rate increased yield by only 14 bu/acre.

Comparisons of grain yield between single preplant K rates and split rates (90 lb preplant vs. 45-lb preplant plus 45 sidedressed or 135 lb preplant vs. 90 lb preplant plus 45 lb sidedressed) were not consistently different within a site and across sites. The largest differences were at Site 2, the drought-affected site, where only sidedressed K increased yield, where 90-lb split and the 135-lb split were 6 and 9 bu/acre higher than the single applications, respectively. Rainfall amounts and distribution might explain the results at this site. Rainfall for the periods of time broadcast application to planting, planting to sidedressing (V5-V6 stage), and sidedressing to the R1 to R2 stage were 1.8, 6.4, and 2.4 inches, respectively. Therefore, low precipitation between the broadcast application and planting could explain greater efficiency of the split applications. For the other sites the differences were smaller, however, often yield was higher for the single applications. On average across the two rate comparisons and across sites, the split applications were only 2 bu/acre higher than the single applications.

Figure 2 shows that preplant K fertilization greatly increased ear-leaf K concentrations at all sites, including the two southern Iowa droughty sites, either linearly or exponentially as the preplant K rates increased and up to the high-testing treatment. This large effect of K on ear-leaf concentrations has been observed before in Iowa, even in high-testing soils, and is b because vegetative corn tissues have a very high limit for K uptake and accumulation. The additional response to sidedressed K rate was not statistically significant at Sites 3 and 4, and was very small at the other sites. Corn growth at Site 3 was limited by drought but this was not the case at Site 4. Rainfall during the 2-3 weeks before and after sidedressing (not shown) did not explain the lack of leaf K concentration response at Site 4 compared to the other sites.

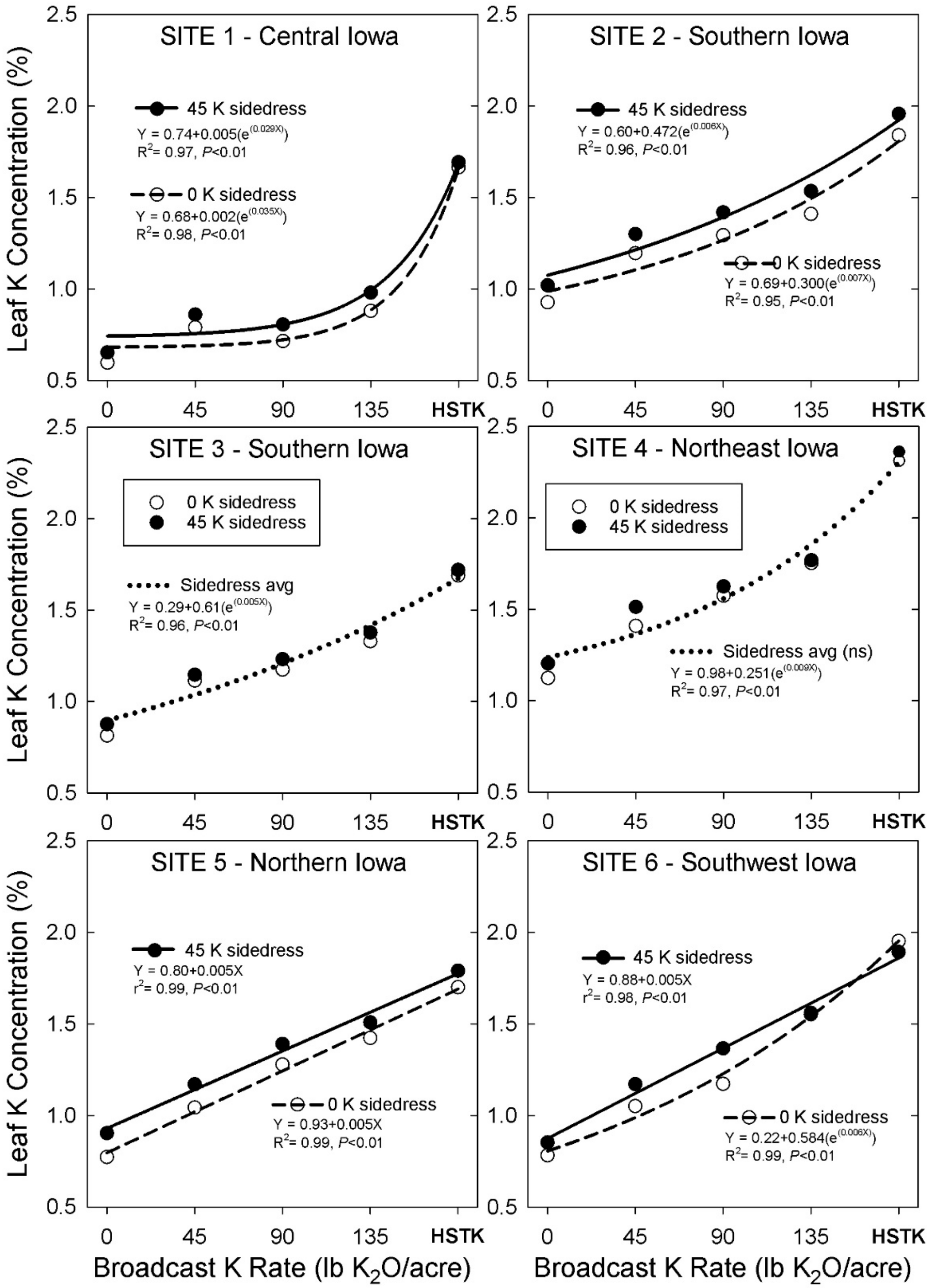

Fig. 2. Corn ear-leaf K concentration response to preplant and sidedressed K fertilization at six sites in 2017. HSTK, high-testing preplant treatment.

Figure 3 shows that as is usually the case in corn K fertilization had little or no effect on grain K concentrations. Research has shown that a very small proportion of absorbed K is partitioned to the grain in corn, and dilution in the dry mater when there is a response to K further makes difficult to detect increased grain K concentrations. There was a statistically significant grain K concentration increase from preplant K at Site 4 but the increase was very small.

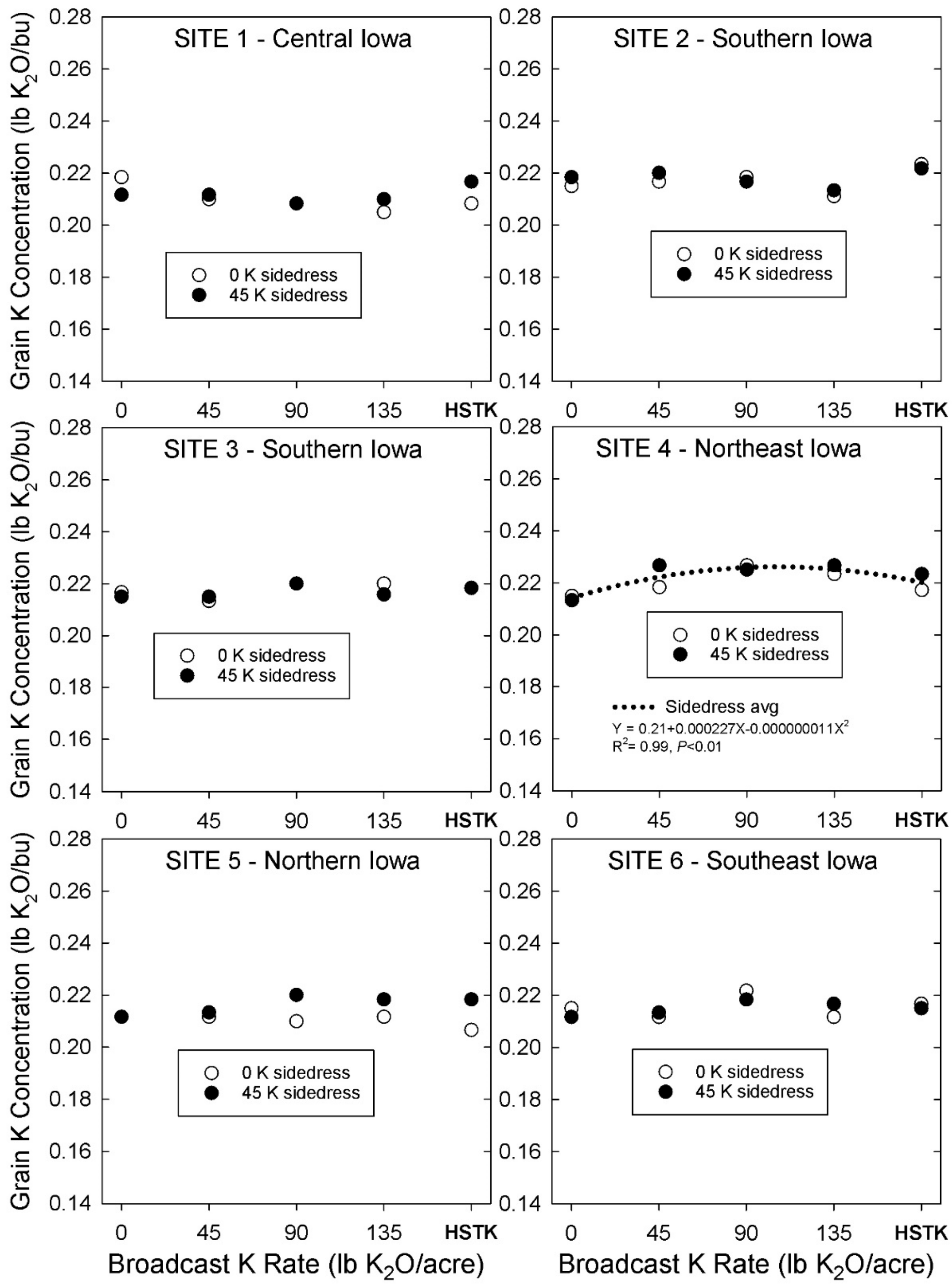

Fig. 3. Corn grain K concentration response to preplant and sidedressed K fertilization at six sites in 2017. HSTK, high-testing preplant treatment.

Figure 4 shows results for K removed with grain harvest. Given generally no K effect on grain K concentration, K removal results followed closely the yield results at most sites. This has been observed in many previous K fertilization trials. There were very small K removed responses to preplant K at the drought-affected Sites 2 and 3 but moderate to large responses at the other sites. Responses to additional sidedressed K were statistically significant only at Sites 1, 2, 4, and 5 and only for preplant rates of 0 and 45 lb K_2O/acre with the exception of Site 5, where the response was similar for all preplant treatments. This is explained by non-significant K concentration increases for 90-lb preplant rates or higher (Fig. 3). The lowest and highest K removed treatment means were 25 lb K_2O/acre (Site 2 non-fertilized control) and 50 lb K_2O/acre (Site 5 with 135 lb K_2O/acre preplant plus sidedressed K).

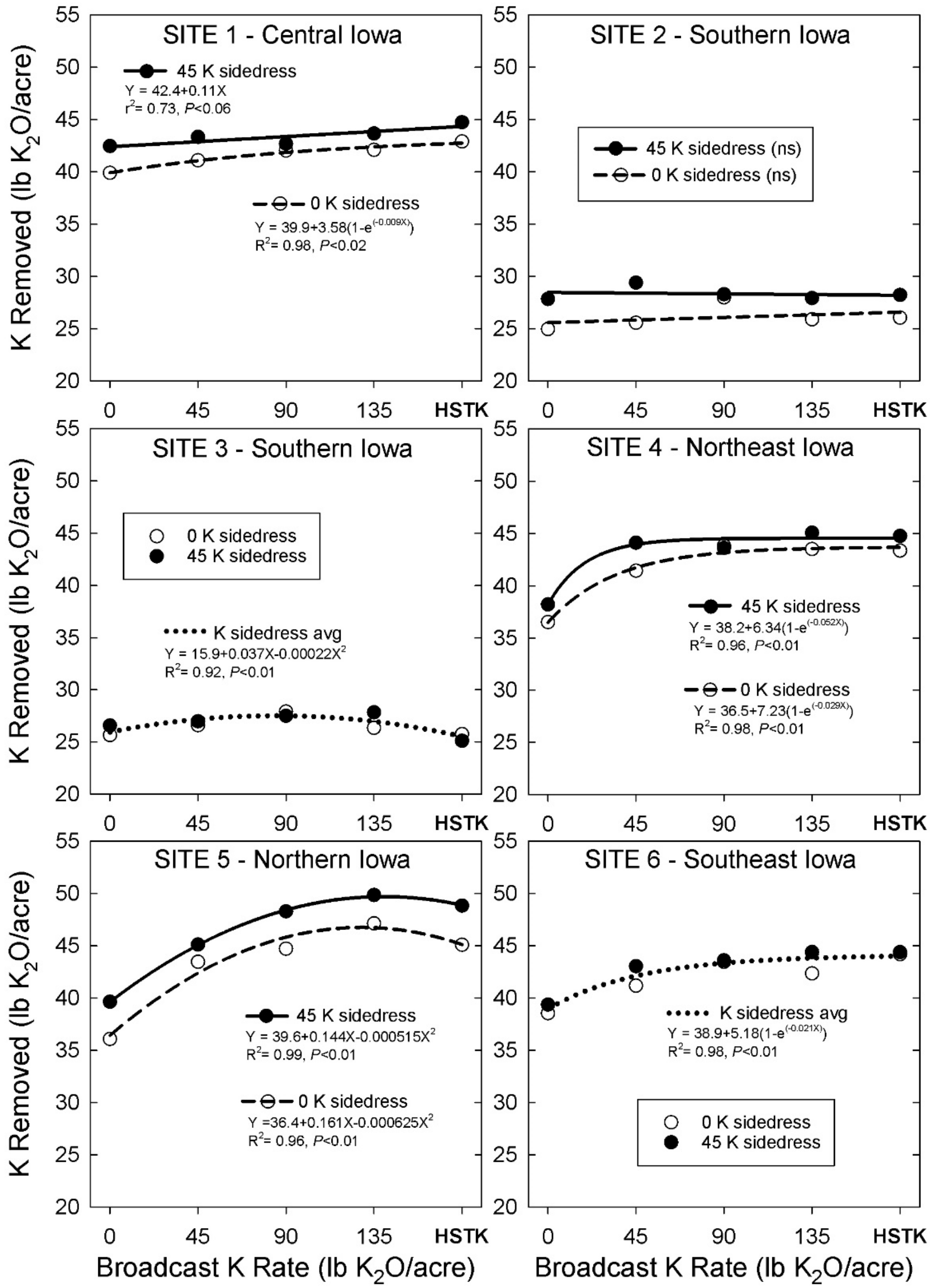

Fig. 4. Response of K removed with corn grain harvest to preplant and sidedressed K fertilization at six sites in 2017. HSTK, high-testing preplant treatment.

Results for 2018

Figure 5 shows the grain yield results for six new corn trials conducted in 2018. Yield levels for the highest yielding treatment mean were 229, 224, 222, 203, 238, and 181 bu/acre for Sites 7, 8, 9, 10, 11, and 12, respectively.

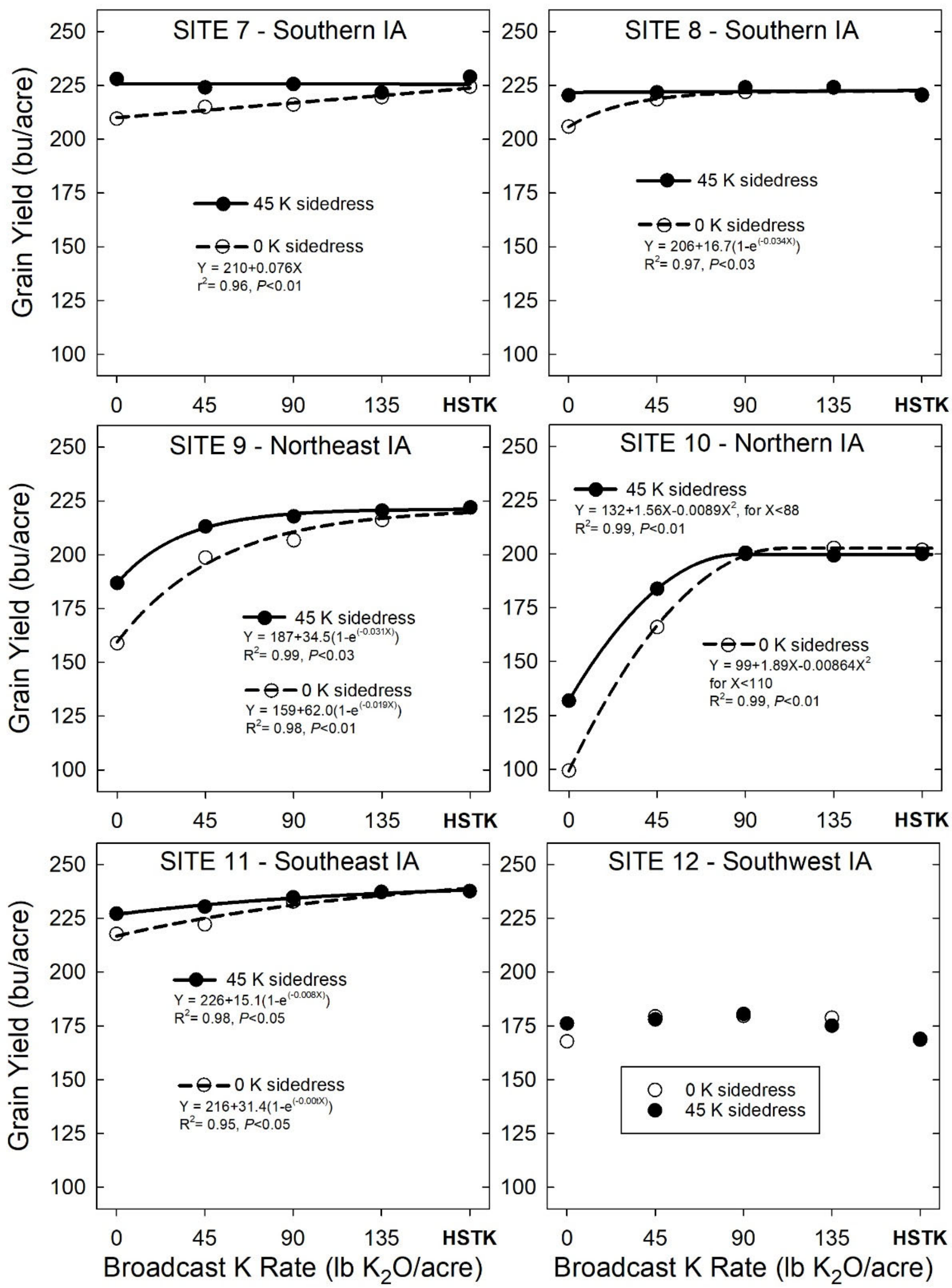

Fig. 5. Corn grain yield response to preplant and sidedressed K fertilization at six sites in 2018. HSTK, high-testing preplant treatment.

Yields at Sites 7 and 8 were within expectations for the soils in these southern Iowa sites. Lower than expected yield at Sites 9 (northeast Iowa) and 10 (northern Iowa) is explained by excessive spring rainfall, which reduced the final plant stand than desirable at Site 9 (although the planting date was timely) and delayed planted date at Site 10 (ten days later than the latest recommended planting date). Lower than normal yield at Site 12 is explained by green snapping by strong wind in early July that reduced plant population and also introduced very high yield variability.

There were grain yield increases from broadcast preplant K fertilization at five sites. The exception was Site 12. Yield increases from preplant K were expected at all sites because STK of the trial area to which preplant K was applied was Very Low to Optimum by the dry K test and Very Low to borderline between Low and Optimum by the moist test (Table 2). Rates of 90, 45, and 90 lb K_2O/acre maximized yield at Sites 7, 8, and 11, respectively. At Site 12 (where green snapping decreased plant population and yield) apparent yield increases or decreases compared with the non-fertilized control were not statistically significant. At Sites 9 and 10 there were large yield increases because STK was Very Low or Low, and maximum yield was attained by the 135-lb rate at Site 9 and the 90-lb rate at Site 10. Yield for the high-testing treatment never was higher than for the 135-lb preplant rate (130 lb K_2O is the rate recommended for corn in Iowa for soils testing Very Low in K).

Sidedressed K fertilizer increased grain yield at most sites with the only exception of the wind-affected Site 12, and only for preplant rates of 90 lb K_2O/acre or lower (Fig. 5). The yield increase was the largest for the control that received no preplant K, but the sidedressed rate was sufficient to maximize yield only at Sites 7 and 8. With preplant K applied, the additional yield increase by sidedressed K maximized yield for the 45lb rate at Site 8, the 90-lb rate at Sites 10 and 11, and the 135-lb rate at Sites 7 and 9. On average across the five yield responsive sites, the 45-lb preplant rate without sidedressed K increased yield by 30 bu/acre over the non-fertilized control whereas the similar 45-lb sidedressed rate increased yield by only 21 bu/acre.

As was observed in 2017, comparisons of grain yield between single preplant K rates and split rates were not consistently different across sites. The largest differences were at Site 1, where 90-lb and 135-lb split rates were 8 and 6 bu/acre higher than the single applications, respectively, and at Site 10, where the 90-lb and 135-lb single applications were 17 and 3 bu/acre higher than the split applications. For the other sites differences were smaller. Rainfall amounts and distribution only partially explain the difference between Sites 7 and 10. At Site 7, rainfall from K broadcasting to planting, planting to sidedressing (V5-V6 stage), and sidedressing to R1-R2 stages were 0.98, 4.7, and 9.0 inches, respectively. Therefore, low precipitation between the broadcasting and planting dates could explain lower efficiency of the single applications. At Site 10, however, rainfall for similar periods of time were 6.8, 4.6, and 13.8 inches, respectively, which do not explain a greater efficiency of the single applications. On average across the two rate comparisons and sites, the yield difference between single and split applications was zero.

Figure 6 shows that preplant K fertilization greatly increased ear-leaf K concentrations at all sites, even when the grain yield response was very small. This results also was observed in 2017 and for the reasons explained before. There were corn ear-leaf K increases from sidedressed K at most sites with the only exception of Site 7. We cannot explain the lack of response to sidedressed K at Site 7 because sidedressed K did increase grain yield mainly for preplant K rates of 0 and 45 lb K_2O/acre. At the responsive sites, the leaf K increases were large only at Sites 8 and 9, and at Site 9 decreased sharply as the preplant K rate increased. Study of rainfall amounts and distribution did not explain the observed differences. Leaf K concentration increases from the 45-lb preplant rate were much larger than for the similar sidedressed K rate with the only exception of Site 8, where increases were similar.

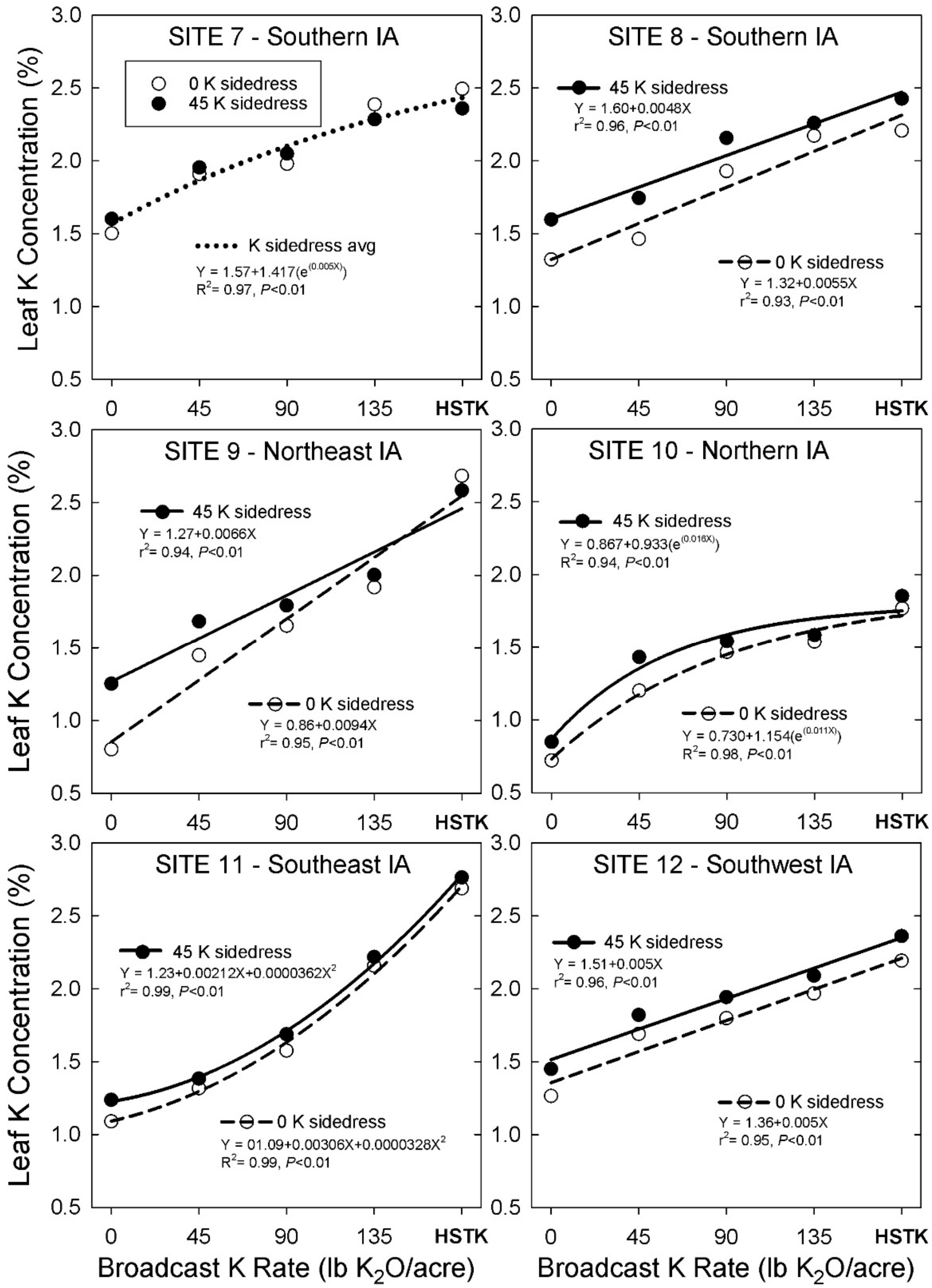

Fig. 6. Corn ear-leaf K concentration response to preplant and sidedressed K fertilization at six sites in 2018. HSTK, high-testing preplant treatment.

Figure 7 shows that the grain K concentration increases from K fertilization were not statistically significant at four sites, and increases for Sites 9 and 11 were very small. At Site 9, only sidedressed K increased concentrations with a similar increase for all preplant treatments. At Site 11, concentrations increased exponentially as preplant K increased, but sidedressed K increased concentrations only for the high-testing treatment.

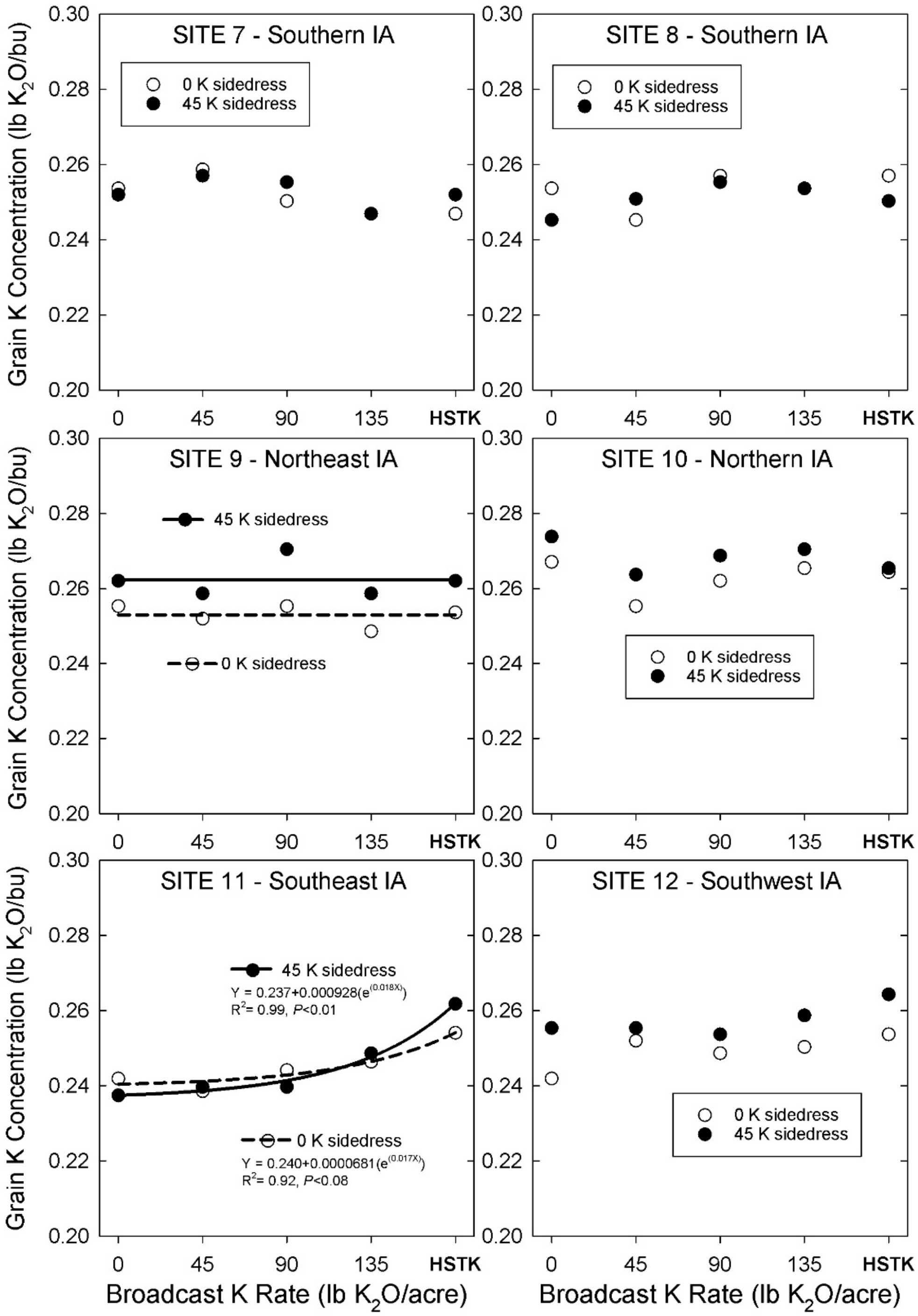

Fig. 7. Corn grain K concentration response to preplant and sidedressed K fertilization at six sites in 2018. HSTK, high-testing preplant treatment.

Figure 8 shows that K removal responses tended to follow results for grain yield given very small or no K effects on grain K concentrations. There were statistically significant removal increases at Sites 9 and 10 from both preplant and sidedressed K, and at Site 11 with increases only from preplant K. The lowest and highest K removed treatment means were 23 (Site 10 non-fertilized control) and 55 lb K_2O/acre (Site 11 high-testing treatment plus sidedressed K).

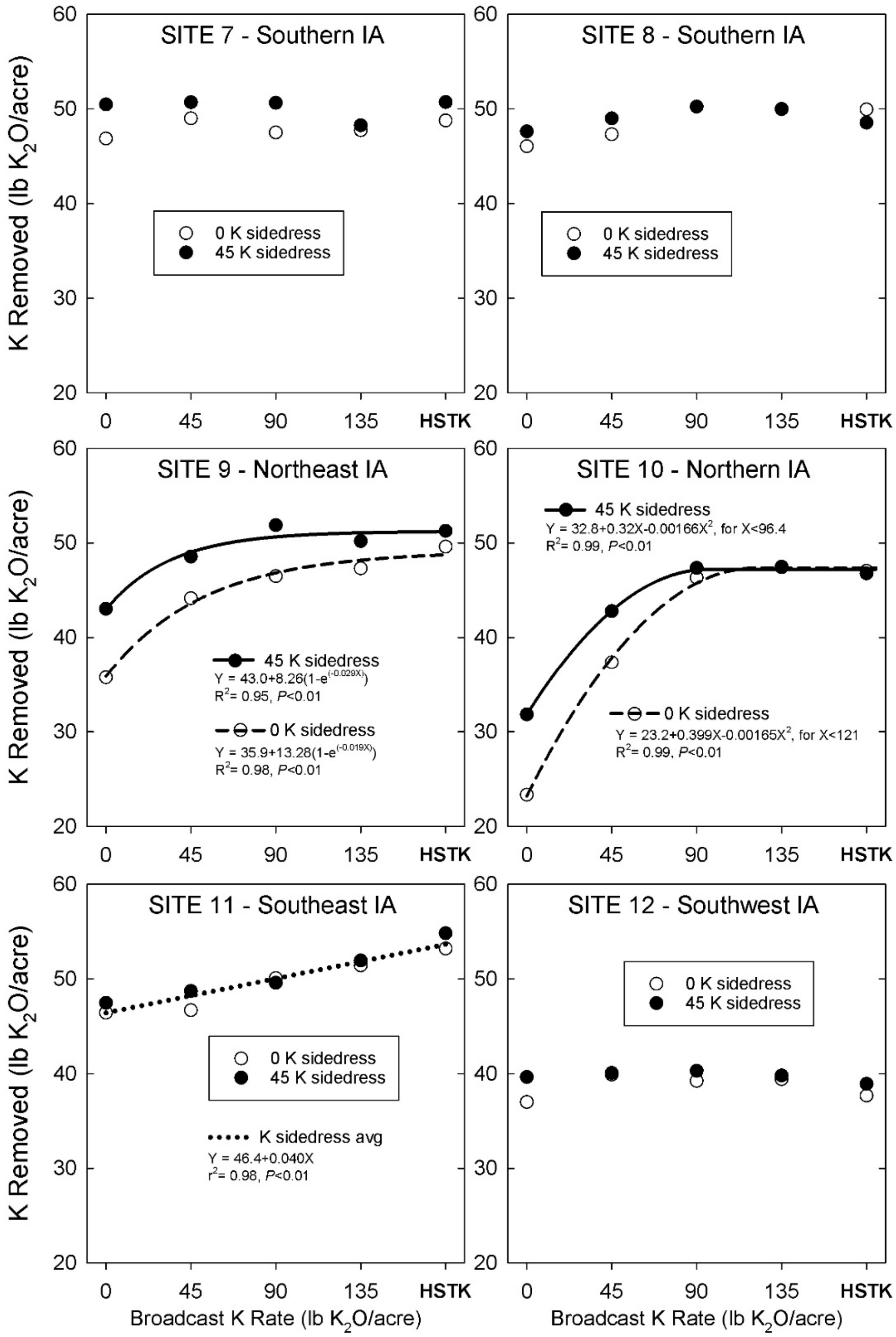

Fig. 8. Response of K removed with corn grain harvest to preplant and sidedressed K fertilization at six sites in 2018. HSTK, high-testing preplant treatment.

Summary of Results

The study involved twelve field trials, six in 2017 and six in 2018, in areas where corn and soybean production predominate, encompassed nine different soil series and a wide range of weather conditions commonly observed across Iowa. The results for each site and year demonstrated that weather conditions, mainly rainfall, determined most of the variation observed across trials for yield levels with or without K fertilization. There were small yield potential differences among the soils included in the study but they were overridden by varying rainfall. The following points summarize the most important results concerning measured crop responses to broadcast, preplant granulated potash and to sidedress fertilization at the V5-V6 growth stage with injected liquid fertilizer.

1. Corn yield response to broadcast preplant K fertilization and the rates that maximized yield were within expectations according to Iowa STK interpretations and recommended rates, although there were a few exceptions mainly due to weather conditions that limited yield and the response to K. At all sites, one or more of the preplant K rates applied, which were within recommended rates for corn, attained a yield level similar to yield for the high-testing treatment.

2. A crop yield response to sidedressed liquid K fertilizer was observed only when there was no preplant K applied or when the broadcast preplant rate was lower than ISU recommended rates with only one exception. The exception was at a site where drought severely limited yield for all preplant treatments (on average 137 bu/acre) but there was a small response to sidedressed K for all preplant treatments (on average 10 bu/acre). Across all twelve sites, the 45-lb preplant rate increased yield by 21 bu/acre whereas the increase from the 45-lb sidedressed was 16 bu/acre.

3. The yield increase from a preplant rate of 45 lb K_2O/acre was larger than the increase from a similar sidedressed K rate applied to the non-fertilized control at most sites. The only exception was the aforementioned drought-affected site. On average across the responsive sites, the yield increases from preplant or sidedressed 45-lb rates was 25 and 18 bu/acre, respectively. Comparisons of yield between single preplant K rates and split rates were not consistently different across sites. Rainfall amount and distribution did not explain the mostly small differences, and the single or split applications did not differ on average across sites.

4. Ear-leaf K concentrations were greatly increased by broadcast preplant fertilization at all sites, the increase was linear or exponential, and the relative increase was four to five times greater than for grain yield. This was observed before, and is explained by large K accumulation in corn vegetative tissues and a high uptake limit. The sidedressed K fertilizer did not increase leaf K concentrations at three sites, the increases at other sites was very small, and with few exceptions the magnitude of the response tended to decrease with increasing preplant K rates.

5. Preplant or sidedressed K applications did not affect the grain K concentration at harvest at nine sites and increases at the other three sites were very small. Therefore, amounts of K removed with grain harvest and increases from K fertilization tended to follow differences in yield level and yield responses to K. The minimum amount of K removed was 23 lb K_2O/acre (for a non-fertilized control) and the maximum was 55 lb K_2O/acre (for a K fertilized treatment at a high yielding site).

Overall Conclusions

The results showed that a broadcast preplant rate of 45 lb K_2O/acre increased both corn grain yield and ear-leaf K concentration much more than a similar rate sidedressed at the V5-V6 growth stage by injecting liquid K fertilizer. Grain yield for single broadcast preplant rates of 90 and 135 lb K_2O/acre compared with split applications with a rate of 45-lb applied preplant and also sidedressed or a 90-lb preplant rate plus a 45-lb sidedressed did not differ consistently, differences were mostly small, and did not differ on average across sites. Therefore, sidedressed liquid K fertilization for corn at the rate used may be a good rescue option when recommended preplant K rates based on soil testing are not applied. Results do not support, however, purposely withholding or reducing preplant K rates to be complemented by K sidedressing.

References Cited

Mallarino, A.P., J.E. Sawyer, and S.K. Barnhart. 2013. A general guide for crop nutrient and limestone recommendations in Iowa. PM 1688. Iowa State University Extension and Outreach.

Acknowledgements

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