Evaluation of Sidedress Fluid Potassium Fertilizer Application for Soybean Production

COMBINATION OF FINAL REPORTS TO
Corteva Agriscience Crop Management Research Program and
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Brief Justification for the Study and Objectives

This project with soybean was the second phase of a larger study that began with corn to evaluate sidedress fluid potassium (K) fertilizer for corn-soybean rotations in Iowa. Although much research and recommendations exist for nitrogen sidedress for corn, scarce research has been conducted for cotton and irrigated corn but none for soybean. The previous of the study showed that fluid K sidedress is effective for corn with lower than recommended preplant K rates. Most farmers apply K for the 2-year corn-soybean rotation before corn, so K sidedress may be an optional strategy to assure soybean K sufficiency. This project phase objectives were to evaluate how fluid K sidedress interacts with broadcast K rates applied to the previous-year corn crop at affecting soybean grain yield, tissue K concentration, and K removed with harvest.

Summary of Procedures

This study developed 12 soybean trials, six in 2018 and six in 2019, on plots of corn trials conducted in 2017 and 2018. Table 1 shows soils and basic properties of trial areas.

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

					Extractable Cations				
Year	Site	Soil Series	pH	OM†	Ca	Mg	Na	CEC‡	Texture
				%	---------- ppm -------			meq/100 g	
2018	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
2019	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 2018 soybean trials were at the central (Site 1), southern (Sites 2 and 3), northeast (Site 4), northern (Site 5), and southeast (Site 6) Iowa State University (ISU) research farms. The 2019 soybean 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.

Detailed procedures and results for the previous corn K sidedress project were published before (Mallarino, 2020). The tillage system for Sites 1 to 11 involved chisel-plowing in the fall and spring light disking or field cultivation but Site 12 was managed with no-tillage. Table 2 shows the ten K application strategies for first-year corn and second-year soybean. The treatments for first-year corn were modifications of treatments for previous trials that had four replications (blocks) each with four low-testing plots and one high-testing plot. Four preplant broadcast K rates (granulated potash) were randomized to the low-testing plots but no K was applied to the high-testing plot. Each plot was 40-foot wide and length was 50 to 60 feet across sites. At the V5-V6 corn growth stage all plots were split into two halves for with/without sidedressed fluid K fertilizer (potassium acetate 0-0-24) injected between the rows (30-inch spacing) to a 4-inch depth. No preplant K was applied for soybean but fluid sidedress K rates applied to the previous year corn were reapplied to the same plots at the V5-V6 growth stage.

Table 2. Potassium fertilization treatments for first-year corn and second-year soybean.

		Corn Treatments		Soybean Treatments		Total
Treatment	Previous history	Broadcast preplant	Injected at V5-V6	Broadcast preplant	Injected at V5-V6	2-year K applied
		---------- lb K_2O/acre ----------				
1	0	0	0	0	0	0
2	0	0	45	0	45	90
3	0	45	0	0	0	45
4	0	45	45	0	45	135
5	0	90	0	0	0	90
6	0	90	45	0	45	180
7	0	135	0	0	0	135
8	0	135	45	0	45	225
9	HSTK†	0	0	0	0	0
10	HSTK†	0	45	0	45	90

† HSTK, plots testing High or Very High in K before corn from previous fertilization.

Soil samples (6-inch depth) were collected after harvesting the previous corn crop (initials for soybean) only from plots that had received no liquid K sidedress and were analyzed by the dry and moist soil K testing procedures supported by ISU and the NCERA-13 regional soil testing committee. All STK values shown are averages for the ammonium-acetate and Mehlich-3 extractants because were comparable and have the same interpretation (Mallarino et al., 2023).

The soybean seed planted in all trials was supplied by Corteva. For trials conducted in 2018 varieties were P24A99X for trials at the central and northern research farms except for Site 4 in which accidentally variety Channel 1818R2X was planted, and P33T19X for trials at the southern farms. For trials conducted in 2019 the varieties were P24A99X at the northern farm, P23A32X at the northeast farm, and P31A22X at the southern, southeast, and southwest farms.

Table 3 shows the soybean planting dates, the fluid K sidedress injection dates, and the actual growth stage at sidedressing. Excessive soil moisture delayed planting dates beyond the desirable late April to the middle of May period at Sites 5 and 11. At Sites 2 and 3 the sidedressing was delayed until the V7-V8 stage due to excessive soil moisture. At Sites 5 and 11 the sidedressing was done earlier than planned because of forecasted rain when soybean was at the V4 stage.

Table 3. Soybean planting date, fluid K fertilizer sidedressing date, and actual growth stage at sidedressing .

Year	Site	Planting Date	Sidedress Date	Growth State
2018	1	18 May	29 June	V5-V6
	2	30 April	30 June	V7-V8
	3	30 April	30 June	V7-V8
	4	7 May	25 June	V5-V6
	5	26 May	18 June	V4
	6	10 May	27 June	V6-V7
2019	7	24 April	2 July	V5-V6
	8	24 April	2 July	V5-V6
	9	17 May	27 June	V5-V6
	10	16 May	27 June	V5-V6
	11	10 June	1 July	V4
	12	4 May	28 June	V5-V6

Trifoliate soybean leaves including petioles were sampled from central rows of all 40 plots of all trials at the R2-R3 stage, dried at 60 C, ground, and analyzed for total K concentration. Soybean grain was harvested from central areas of each plot with plot combines equipped with moisture meters. Grain yield was adjusted to 13% moisture and samples were collected for analysis of K concentration and calculation of K removed with harvest.

Results from Six Soybean Trials Conducted in 2018

Initial soil-test K levels for soybean in 2018.

The previous corn trials provided a good opportunity for the study with a following soybean crop because each trial ended with a wide range STK levels. Table 4 shows initial STK results for the 2018 soybean crop from samples taken in fall 2017 only from plots with no sidedress K for corn. Therefore, STK values reflect residual effects for soybean of the K treatments for the previous year corn crop. As expected, dry or moist STK increased with increasing broadcast K rates applied before corn compared with the control that had received no K fertilization at all sites. Iowa research has shown that frequent and large soybean yield responses are expected with STK within the Very Low or Low interpretation categories, small responses are likely 25% or less of the times with STK in the Optimum category (for which only removal-based maintenance K is recommended), and that responses are unlikely with STK in the High (5%) or Very High (1%) categories (Mallarino et al., 2023).

The STK measured using dry and moist sample handling procedures sometimes did not correspond to the same interpretation category. Previous Iowa research showed that STK measured with the moist sample handing procedure often is lower, needs different interpretation,

and estimates crop K sufficiency better than the dry sample procedure mainly in soils with moderately poor to very poor drainage.

Table 4. Initial soil-test K before planting soybean at the six trials of 2018 as affected by broadcast K rates applied for the previous year (2017) corn crop.

Site	Broadcast K	Dry STK†	Dry Category‡	Moist STK†	Moist Category‡
	lb K_2O/acre		---------- ppm ----------		
1	0	92	Very low	48	Very low
	45	113	Very low	71	Low
	90	108	Very low	72	Low
	135	134	Low	78	Low
	HSTK§	175	Optimum	145	Optimum
2	0	131	Low	66	Low
	45	142	Low	87	Low
	90	148	Low	107	Optimum
	135	166	Low	122	Optimum
	HSTK	196	Optimum	163	High
3	0	115	Very low	59	Very Low‖
	45	135	Low	77	Low
	90	148	Low	93	Low
	135	156	Low	103	Optimum
	HSTK	178	Optimum	136	Optimum
4	0	100	Very low	58	Very Low
	45	104	Very low	72	Low
	90	124	Very Low	83	Low
	135	125	Very Low‖	92	Low
	HSTK	220	Optimum‖	192	High
5	0	139	Low	54	Very Low
	45	161	Low	65	Low
	90	156	Low	73	Low
	135	158	Low	94	Low
	HSTK	200	Optimum	126	Optimum
6	0	117	Very low	59	Low
	45	121	Very Low	82	Low
	90	130	Low	89	Low
	135	145	Low	135	Optimum
	HSTK	203	Optimum	202	Very high

†Dry STK or Moist STK, average soil-test K by the ammonium-acetate and Mehlich-3 extractants using for each dry and moist sample handling procedures. ‡ STK interpretation categories for dry and moist sample handling procedures (from publication PM 1688, Mallarino et al., 2023). § HSTK, treatment with High or Very High STK before corn that did not receive broadcast K for any crop. ‖ Value is borderline between two categories.

Results for soybean grain yield in 2018.

Yield levels for the highest yielding treatment mean at each site were 58, 61, 62, 66, 54, and 70

bu/acre for Sites 1, 2, 3, 4, 5, and 6, respectively (Fig. 1). Excessive rainfall from late April until early June (not shown) at Sites 1 (central Iowa), 2 and 3 (in southern Iowa), and 5 (northern Iowa) may have reduced yield from the expected potential.

Figure 1 shows that without sidedress K application for either crop, yield for plots that had received a broadcast rate of 45 lb K_2O/acre for the previous year corn crop were greater than yield for the not fertilized control at all sites, although increases ranged from 3 (Site 5) to 10 (Site 1) bu/acre. Maximum yield was attained by the 90-lb applied to the previous year corn at Sites 4 and 6 whereas at other sites yield was maximized by the 135-lb rate. Yields for the 135-lb rate applied before corn and for the initially high-testing treatment before corn were statistically similar ($P \leq 0.05$ or ≤ 0.10) at all sites.

The observed soybean yield differences without fresh preplant K rates nor sidedressed K are reasonable because initial STK for soybean of treatments that had received 0 to 145 lb K_2O/acre for the previous year corn was Very Low or Low by the dry or moist sample handling procedures except for Sites 2, 3, and 6 where the moist test was Optimum for the 90-lb or 135-lb rates (Table 4). The dry STK before soybean for the treatment that before the previous year corn tested High or Very High (HSTK) decreased to the Optimum category at all sites. The moist STK also decreased to the Optimum category at Sites 1, 3, and 5 but remained in the High or Very High categories at Sites 2, 4, and 6 (Table 4).

It is important to remember when interpreting STK values and grain yield responses that the rates of 0 to 135 lb K_2O/acre broadcast only before the previous corn crop were lower than those recommended by ISU to apply only once for the 2-year corn-soybean rotation and that the corn harvest removed K from the soils. The recommended 2-year rates that would have been recommended to apply before corn for the 2-year rotation are 245 and 175 the Very Low and Low categories and 130 lb K_2O/acre for the Optimum category assuming yields of corn and soybean of 210 and 70 bu/ac re, respectively (Mallarino et al., 2023).

Sidedressed liquid K fertilizer at 45 lb K_2O/acre increased soybean grain yield significantly compared with no K sidedress at all sites. However, the additional yield increase varied greatly across sites and with broadcast treatments for corn the previous year (Fig. 1). The yield response to sidedressed K was the largest for broadcast rates before corn of 0 or 45 lb K_2O/acre and smaller increases for the 90-lb rate were statistically significant ($P \leq 0.05$ or ≤ 0.10) only at Sites 1, 3, and 5. The additional yield increases by sidedressed K for the 135-b and HSTK treatment before corn were not statistically significant with the only exception of a very small increase for the 135-lb rate at Site 1, which is reasonable because STK was Optimum by both K tests (Table 4) and a removal-based rate is recommended. It is also noteworthy that only at Sites 4 and 6 did sidedressed K result in statistically maximum yield across all treatments applied before corn.

Although excessive early spring delayed planting at a couple of sites and may have reduced grain yield from expected potential, amounts and distribution of rainfall during June and early July (not shown) did not help explain soybean yield responses to sidedressed K across sites. The earlier sidedress application than planned at Site 5 (V4, Table 3) cannot explain a smaller yield response at this site for the two lower broadcast rates before corn because Fig. 2 shows large trifoliate leaf K concentration increases from sidedressed K for these two treatments.

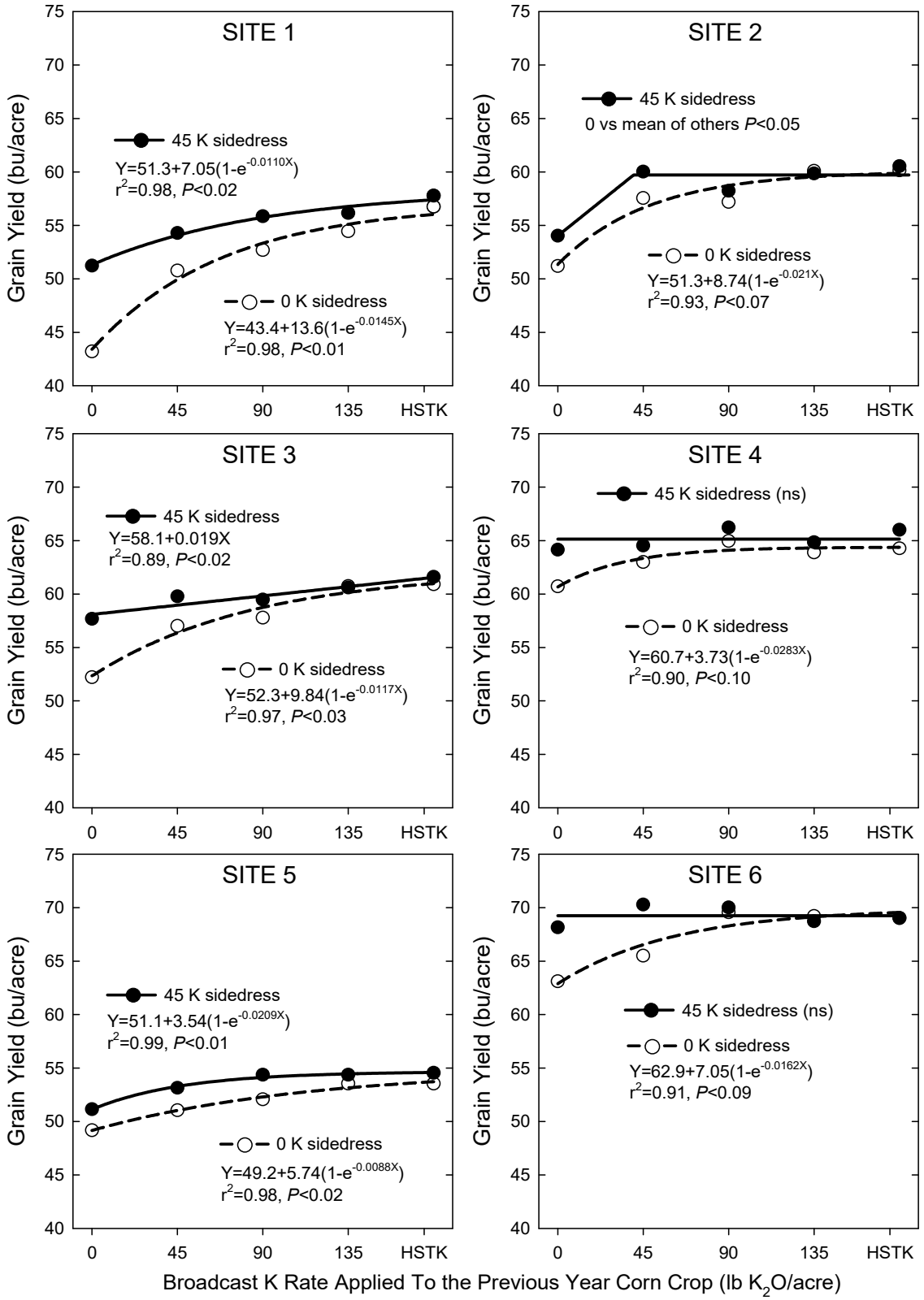

Fig. 1. Soybean yield at six sites in 2018 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

Results for soybean trifoliate leaves K concentrations in 2018.

Figure 2 shows large and statistically significant ($P \leq 0.05$ or ≤ 0.10) residual effects of treatments applied for corn the previous year on soybean leaf K concentrations, with mostly exponential increases with the only exceptions of linear responses at Sites 4 and 5. Sidedressed K at 45 lb K_2O/acre for both crops increased the leaf K concentrations significantly ($P \leq 0.05$ or ≤ 0.10) compared with no sidedress at all sites mostly for broadcast rates before corn lower than 135 lb K_2O/acre with the only exception of Site 4. Increasing leaf K concentrations with increasing K rates or STK levels either linearly or exponentially often even at STK values higher than needed to maximize crop yield is reasonable and expected because it was observed for the corn of the previous study and by previous research in many Iowa fields. This happens because crop vegetative tissues have a high limits for luxury K uptake, and both K uptake and accumulation begin to decrease at supply levels higher than those maximizing dry matter yield.

Results for soybean grain K concentration in 2018.

Figure 3 shows statistically significant ($P \leq 0.05$ or ≤ 0.10) soybean grain K concentration responses to K at all sites, which were proportionally much lower than those observed for leaf K. Previous research has shown that grain K concentration responses to K fertilization rates or increasing STK are much lower than for vegetative tissue of corn or soybean. Without fluid sidedress K application, the grain K concentration increases were linear at most sites with the exceptions of Sites 1 and 3 where the increases were exponential. Sidedressed K increased the grain K concentration significantly compared with no sidedress at all sites but were the largest for rates of 0 and 45 lb K_2O/acre broadcast rates before corn. Significant increases for the 90-lb rate occurred at Sites 3, 4 and 6 and for the 135-lb rate at Sites 3 and 4. Only at Site 4, sidedressed K increased grain K concentration for the treatment before corn testing High or Very High in STK

Results for K removed with soybean grain harvest in 2018.

The responses of K removed with grain harvest (Fig. 4) combined the responses of yield and grain K concentration in different ways across the sites. When sidedress K was not applied, there were differences ($P \leq 0.05$ or ≤ 0.10) among the treatments applied for the previous corn crop at all sites and K removed increased up to the highest rate broadcast before corn of 135 lb K_2O/acre and further up to the HSTK treatment at most sites except Sites 5 and 6. The increasing trends were linear at Sites 1, 3, and 4 but exponential with diminishing increments to a maximum at Sites 2, 5, and 6. Comparisons of the K removal responses in this figure and yield responses in Fig. 1 indicate that K removal responded up to higher STK levels (Table 4) than grain yield, which is explained by increases in both yield and grain K concentration.

The sidedress K application resulted in statistically greater ($P \leq 0.05$ or ≤ 0.10) K removal with soybean grain harvest at all sites (Fig. 4). However, the differences were the largest and of agronomical importance for broadcast rates applied before corn of 90 lb K_2O/acre or less with the only exception of Site 4. The K removed response to sidedressed K sometimes was up to higher broadcast K rates before corn or higher STK (Table 4) than for yield (Fig. 1) can be explained by increases of grain K concentration (Fig. 3).

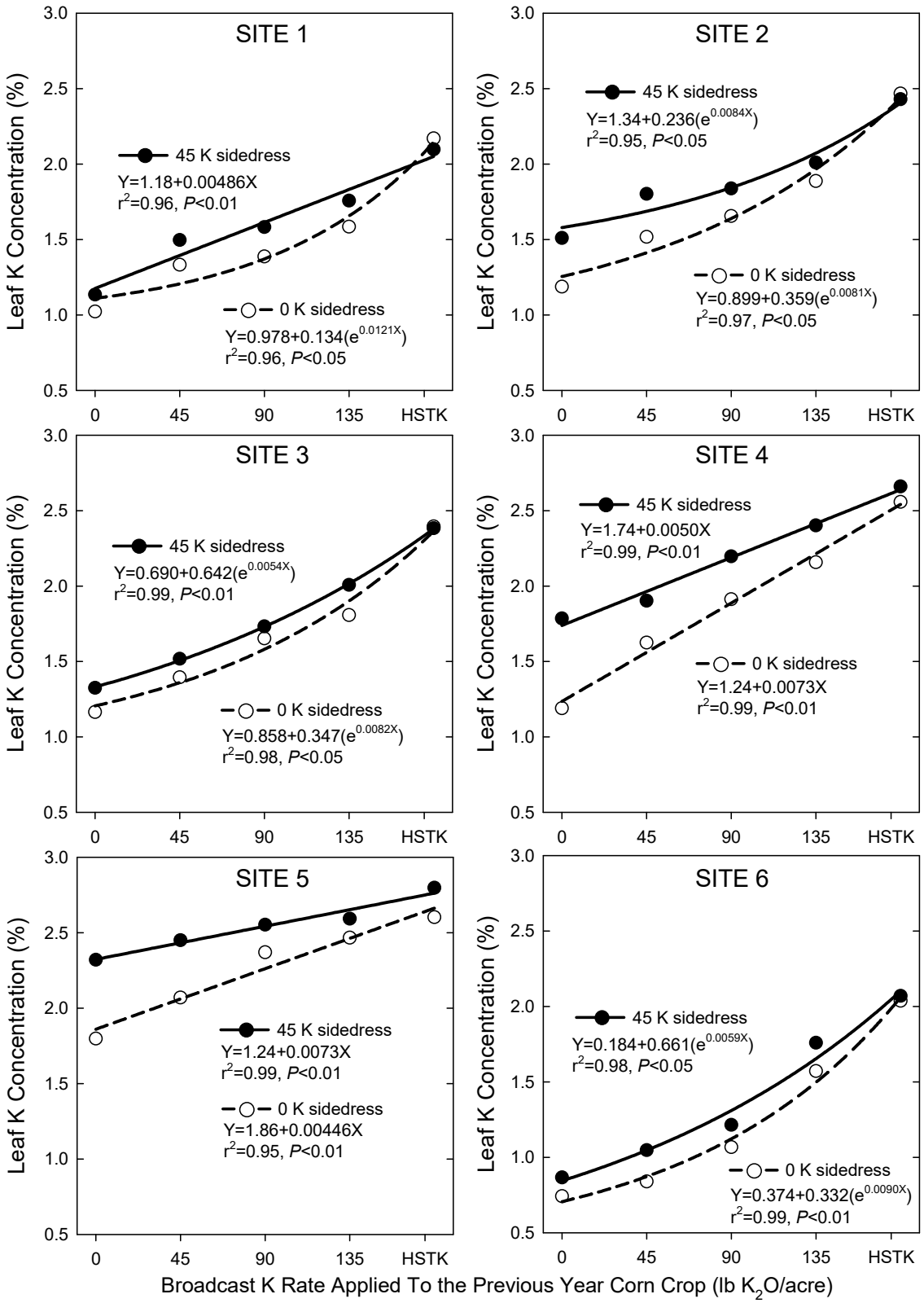

Fig. 2. Soybean trifoliate leaves K concentrations at the R2-R3 growth stages at six sites in 2018 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

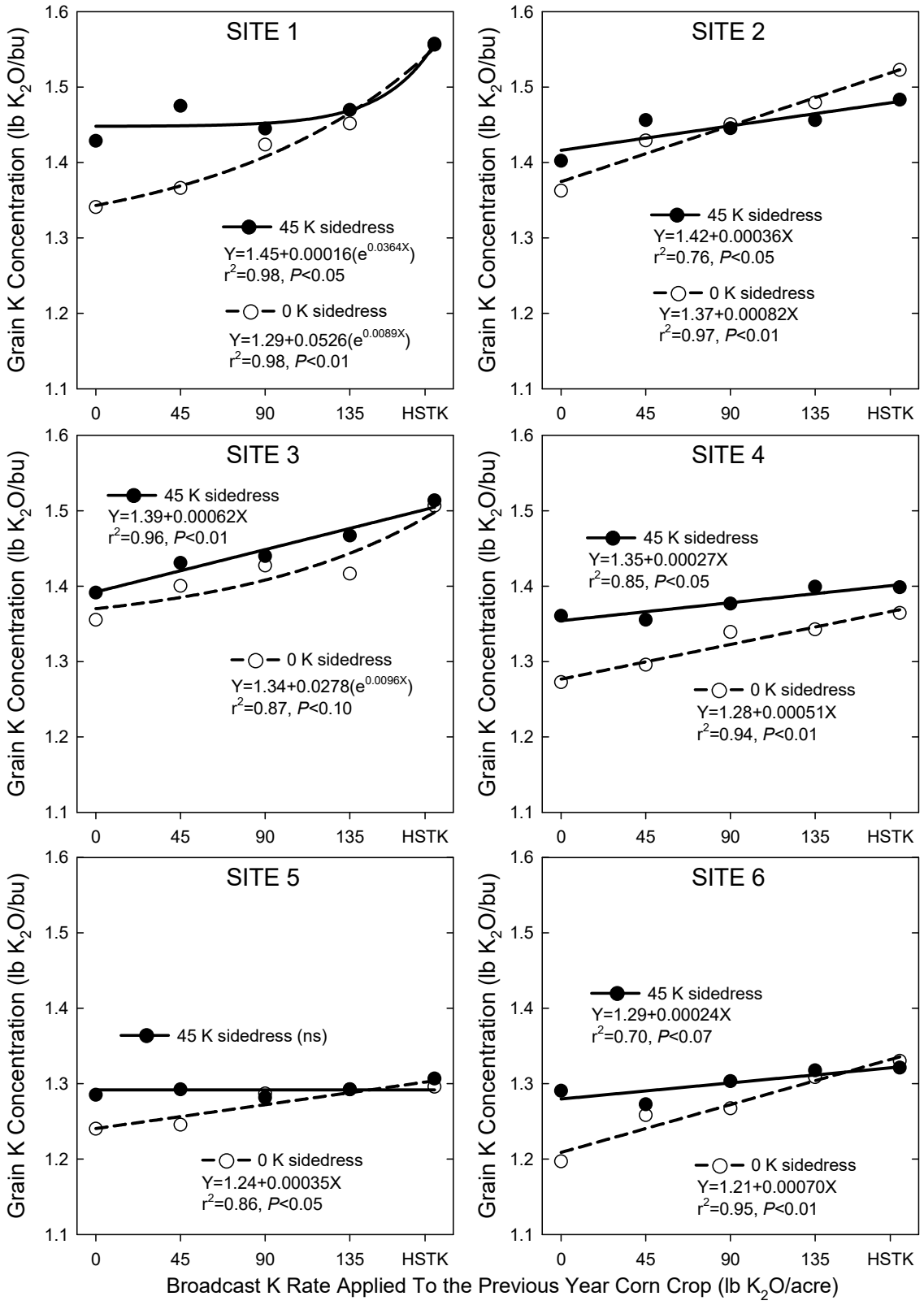

Fig. 3. Soybean grain K concentration at six sites in 2018 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

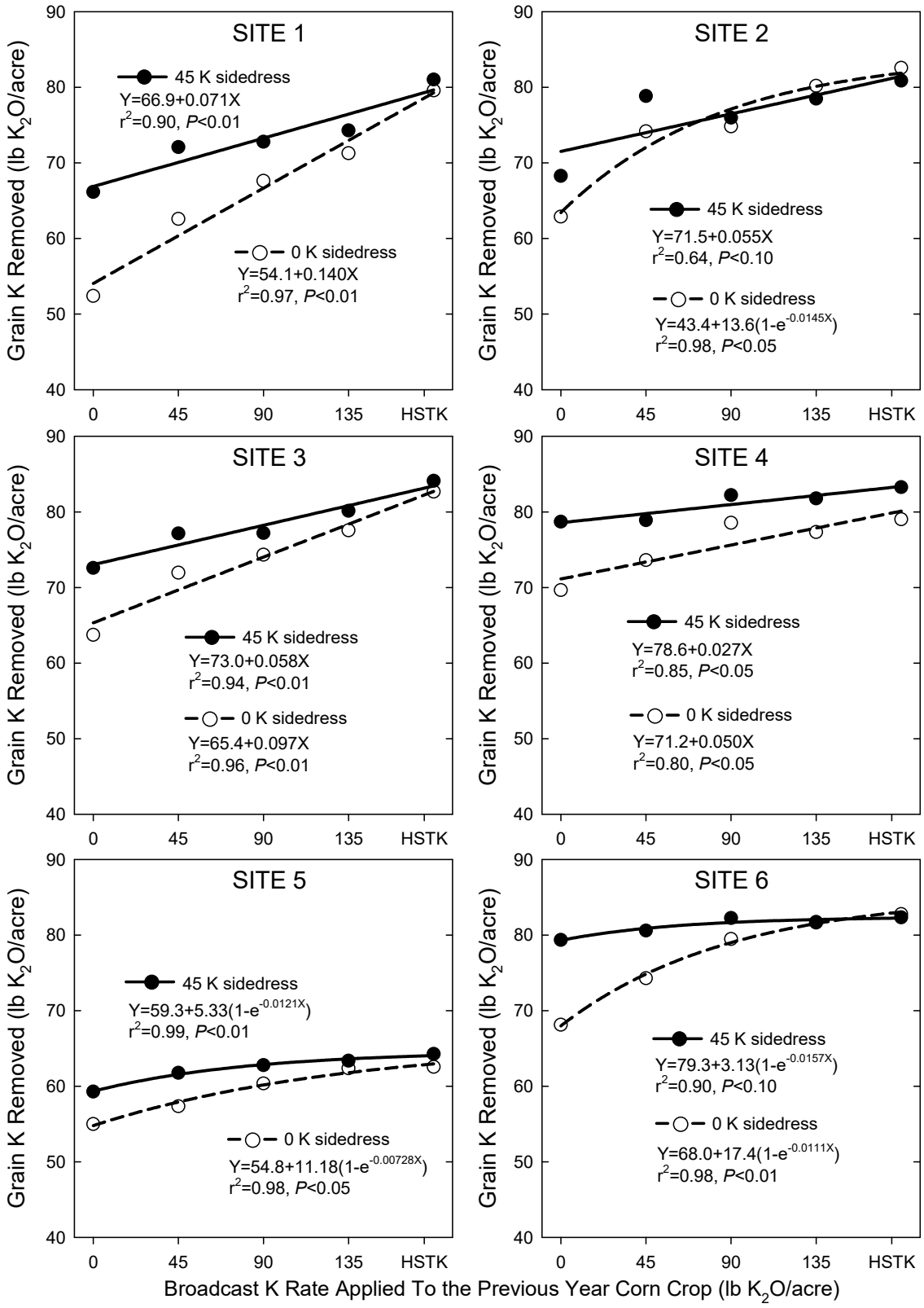

Fig. 4. Potassium removed with soybean harvest at six sites in 2018 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

Summary across trials conducted in 2018.

Figure 5 summarizes averages across the six sites conducted in 2018 for soybean grain yield, leaf K concentration, grain K concentration, and K removed with grain harvest across sites. All soybean measurements increased as broadcast K applied to the previous corn crop or initial STK values for soybean increased. Soybean grain yield without the fluid sidedressed K increased exponentially with decreasing increments up to the HSTK treatment, which tested High or Very High before corn at all sites and received no broadcast K for any crop. However, the difference with yield for the 135-lb rate before corn was very small (about 0.5 bu/acre) and not statistically significant at $P \leq 0.05$ or ≤ 0.10.

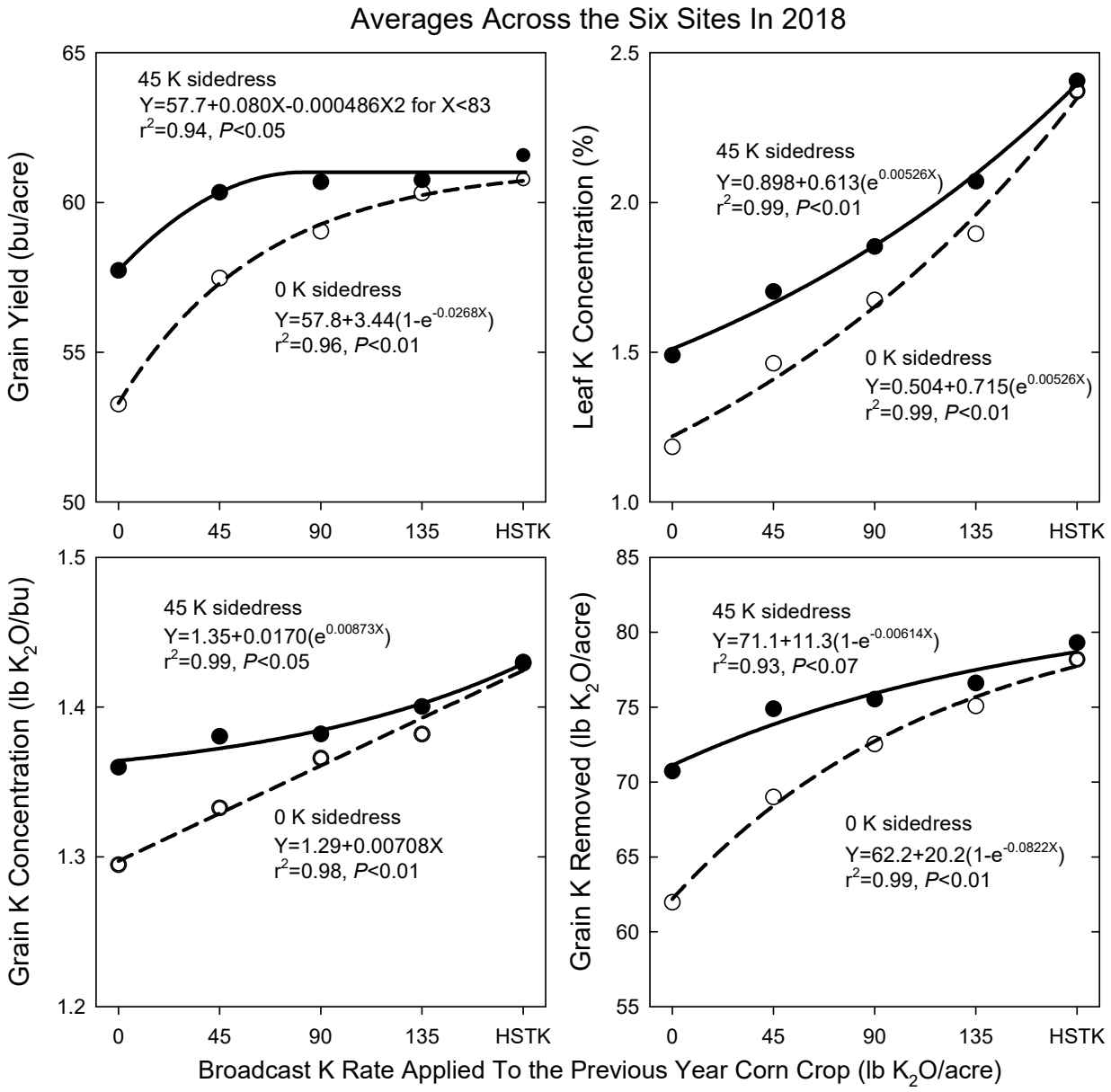

Fig. 5. Averages across six 2018 sites for soybean grain yield, trifoliate leaf K concentration, grain K concentration, and K removed with harvest as affected by treatments before the previous corn crop and fluid sidedressed K to both crops. HSTK = high-testing plots before corn (no preplant K for either crop.

The observed average soybean grain yield response across sites in Fig. 5 without K sidedressing agrees with the observed average initial STK for soybean across sites shown in Table 5, which shows STK for each preplant treatment before corn crop but only for pots that did not receive sidedressed K.

Table 5. Average initial soil-test K for soybean across all sites conducted in 2018 as affected by broadcast K rates applied for the previous year (2017) corn crop.

Broadcast K	Dry STK†	Dry Category‡	Moist STK	Moist Category‡
lb K_2O/acre	-- ppm --		-- ppm --	
0	99	Very low	49	Very low
45	111	Very Low	65	Low
90	116	Low	74	Low
135	126	VL-Low§	89	Low
HSTK⁋	167	Optimum	138	Optimum

†Dry STK or Moist STK, average soil-test K by the ammonium-acetate and Mehlich-3 extractants using dry and moist testing procedures. ‡ Interpretation categories (Mallarino et al., 2023). § Value is borderline between two categories. ⁋ HSTK, treatment with High or Very High STK before corn that did not receive broadcast K for any crop.

The dry STK values were Very Low (0 to 125 ppm) for broadcast rates before corn of 0, 45, and 90 lb K_2O/acre, borderline between Very Low and Low (126 to 170 ppm) for the 135-lb rate, and Optimum (171 to 220 ppm) for the treatments that was high-testing before corn (HSTK) and received no K for either crop. Moist STK was in the same interpretation category for some treatments but not others, being Very Low (0 to 60 ppm) for the control (no K applied to either crop), Low for rates of 45, 90, and 135 lb K_2O/acre before corn, and Optimum (101 to 150 ppm) for the high-testing treatment before corn.

Low STK for several treatments is not surprising because broadcast rates before corn were lower than the recommended to apply only once for the 2-year rotation and corn removed K soil K. Rates for the 2-year rotation are 245 and 175 lb K_2O/acre for the Very Low and Low categories and 130 lb K_2O/acre for the Optimum category assuming corn and soybean yields of 210 and 70 bu/acre, respectively (Mallarino et al., 2023). The recommended preplant K rates for soybean would have been 145 and 110 lb K_2O/acre for the categories Very Low and Low and a removal-based rate of 73 lb K_2O/acre for the observed maximum yield of 61 bu/acre.

With sidedressed K soybean yield increased following a quadratic-plateau response with an estimated maximum at 83 lb K_2O/acre broadcast before corn (Fig. 5). Therefore, the additional yield increase with the sidedressed 45-lb rate was large (5 bu/acre) when no K had been applied before corn, moderate (4 bu/acre) for the 45-lb rate, small (2 bu/acre) for the 90-lb rate, and very small (not statistically significant) for the 135-lab rate and the high-testing treatment before corn.

Figure 5 also shows that the average leaf K concentration response to K was proportionally the largest and the grain K concentration response the lowest among the four crop measurements. Both K concentrations increased exponentially or linearly with increasing K broadcast before corn or residual STK (Table 5) but K removed with grain harvest increased with decreasing increments to a maximum. Sidedressed K for the high-testing treatment before corn (no broadcast K for either crop) did not result in additional increases for any soybean measurement.

Results from New Six Soybean Trials Conducted in 2019

Initial soil-test K levels for soybean

Table 6 shows the initial STK results for the 2019 soybean crop for samples taken in fall 2018 after the previous year corn harvest from plots that received no sidedress K.

Table 6. Initial soil-test K before planting the six soybean trials in 2019 as affected by broadcast K rates applied for the previous year (2018) corn crop.

Site	Broadcast K	Dry STK†	Dry Category‡	Moist STK	Moist Category
	lb K_2O/acre	ppm		ppm	
7	0	130	Low	97	Low
7	45	158	Low	141	Optimum
7	90	156	Low	123	Optimum
7	135	195	Optimum	200	High⁋
7	HSTK§	188	Optimum	194	High
8	0	109	Very Low	91	Low
8	45	122	Very Low	97	Low
8	90	155	Low	146	Optimum
8	135	172	Optimum	170	High
8	HSTK	176	Optimum	190	High
9	0	98	Very low	67	Low
9	45	98	Very low	80	Low
9	90	122	Very Low	111	Optimum
9	135	128	Low	149	Optimum⁋
9	HSTK	270	High⁋	370	Very high
10	0	146	Low	71	Low
10	45	155	Low	77	Low
10	90	161	Low	106	Optimum
10	135	178	Optimum	122	Optimum
10	HSTK	232	High	217	Very high
11	0	153	Low	116	Optimum
11	45	161	Low	124	Optimum
11	90	208	Optimum	222	Very high
11	135	283	Very high	246	Very high
11	HSTK	351	Very high	438	Very high
12	0	176	Optimum	95	Low
12	45	186	Optimum	106	Optimum
12	90	200	Optimum	127	Optimum
12	135	208	Optimum	135	Optimum
12	HSTK	261	High	249⁋	Very high

†Dry STK or Moist STK, average soil-test K by the ammonium-acetate and Mehlich-3 extractants for dry and moist sample handling procedures. ‡ STK interpretation categories (Mallarino et al., 2023). § HSTK, treatment with High or Very High STK before corn that did not receive broadcast K for any crop. ⁋ Value is borderline between two categories.

The STK values in Table 6 reflect the residual effects for soybean of the broadcast K treatments that had been applied for corn. For broadcast rates before corn of 0, 45, and 90 lb K_2O/acre dry STK was Very Low or Low across sites except for Sites11 and 12 where was Optimum but moist STK was Low to Optimum. For the 135-lb broadcast rate and the high-testing treatment before corn dry STK was Optimum to High except for Sites 9 (where was Low) and (where was Very High) but moist STK ranged from Optimum to High for the 135-lb rate broadcast before corn and High to Very High for the high-testing treatment before corn.

Results for soybean grain yield in 2019.

Soybean grain yield levels (Fig. 6) varied only slightly across trials as affected by soil yield potential interacting with local weather conditions. The yield level for the highest yielding treatment mean at each site was 74, 69, 68, 66, 71, and 61 bu/acre for Sites 7, 8, 9, 10, 11, and 12, respectively. At most sites, the grain yield level was approximately similar or higher than the site average for the last few years. Yields were good even at Site 11 where planting was delayed beyond the desirable date (Table 3) due to excess soil moisture.

Figure 6 also shows that soybean yield without sidedress K application increased ($P \leq 0.05$ or ≤ 0.10) in response to preplant broadcast K rates that had been applied for the previous year corn crop at all sites. The yield increases were linear or exponential with decreasing increments to a maximum at Sites 7, 9, 10, and 12 but up to a high plateau yield with the 90-lb rate at Site 8, and estimated 179-lb rate at Site 9, and the 135-lb rate at Site 11. The largest yield increases were observed at Site 9, which may be explained by lower STK compared with other sites mainly for the dry K test (Table 6).

Sidedressed liquid K fertilization increased ($P \leq 0.05$ or ≤ 0.10) soybean yield in 2019 compared with the residual effect of rates applied before corn at all sites with the only exception of Site 8 (Fig. 6). At the five responsive sites the magnitude of the additional increases varied greatly across sites and treatments applied before corn the previous year. The additional yield increases from sidedressed K were statistically significant up to the 135-lb rate before corn at Site 1, up to the 90-lb rate at Sites 9 and 10, and only up to the 45-lb rate at Sites 11 and 12. Study of rainfall amounts and distribution during the 2019 growing season (not shown) did not explain the not statistically significant or very small grain yield response to fluid sidedressed K at Site 8.

Results for soybean leaves K concentrations in 2019.

Figure 7 shows that as was the case in the 2018 trials, there were large and statistically significant ($P \leq 0.05$ or ≤ 0.10) soybean leaf K concentration responses to K at all sites. The leaf K responses without K sidedress application to increasing rates applied for the previous corn crop (or residual STK for soybean shown in Table 6) were exponential at Sites 9 and 11 and linear at the other sites. Sidedressed K increased the leaf K concentrations significantly compared with no sidedress at all sites, but increases were large only at Sites 8 and 9, with increases up to the 135-lb broadcast rate before corn at Site 8 and the HSTK treatment at Site 9. Responses to sidedress K at the other three sites were moderate at Site 7 for most treatments before corn and statistically significant but small and inconsistent for a few treatments before corn at Sites 10, 11, and 12.

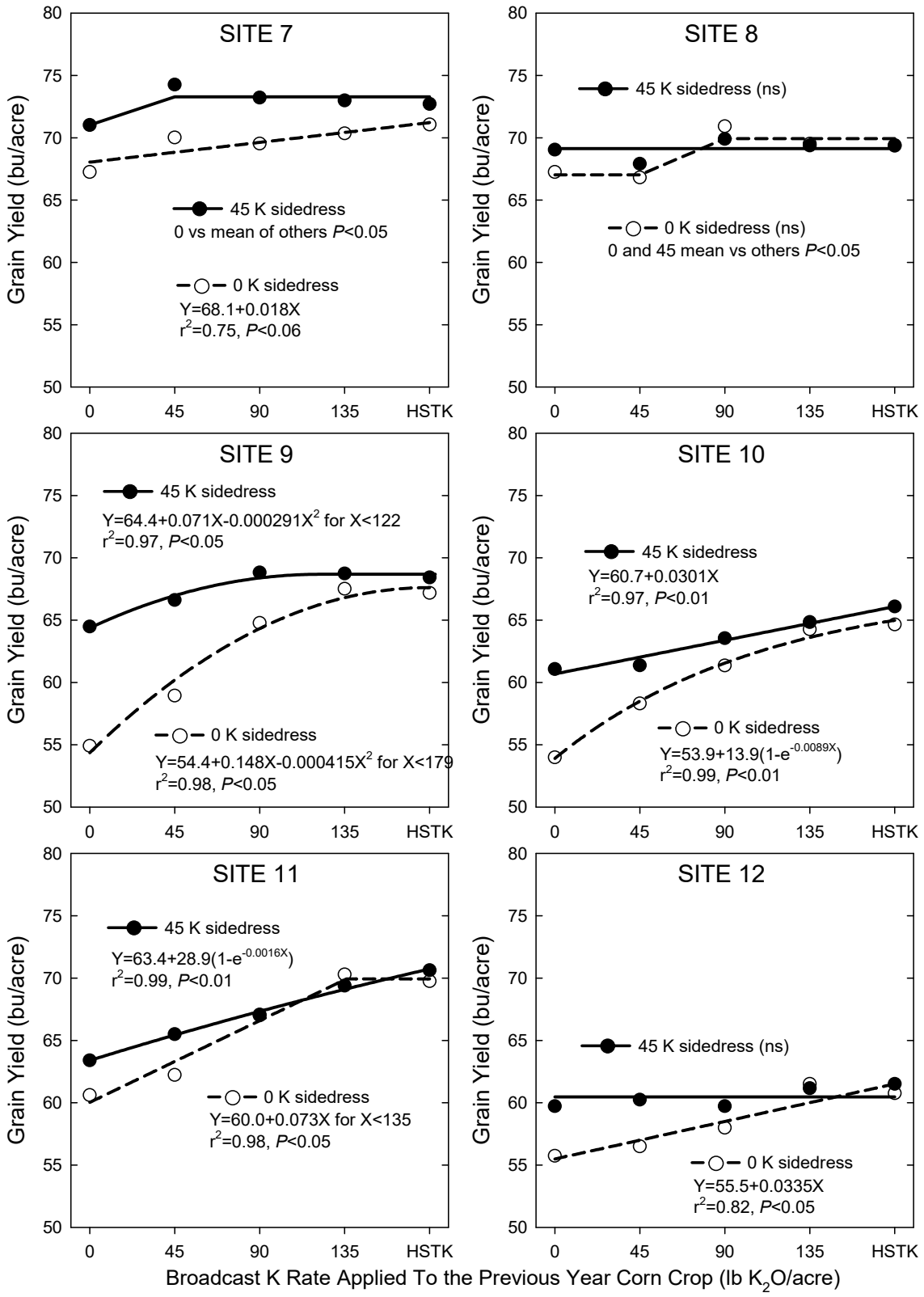

Fig. 6. Soybean yield at six sites in 2019 as affected by broadcast K applied for the previous corn crop and fluid K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

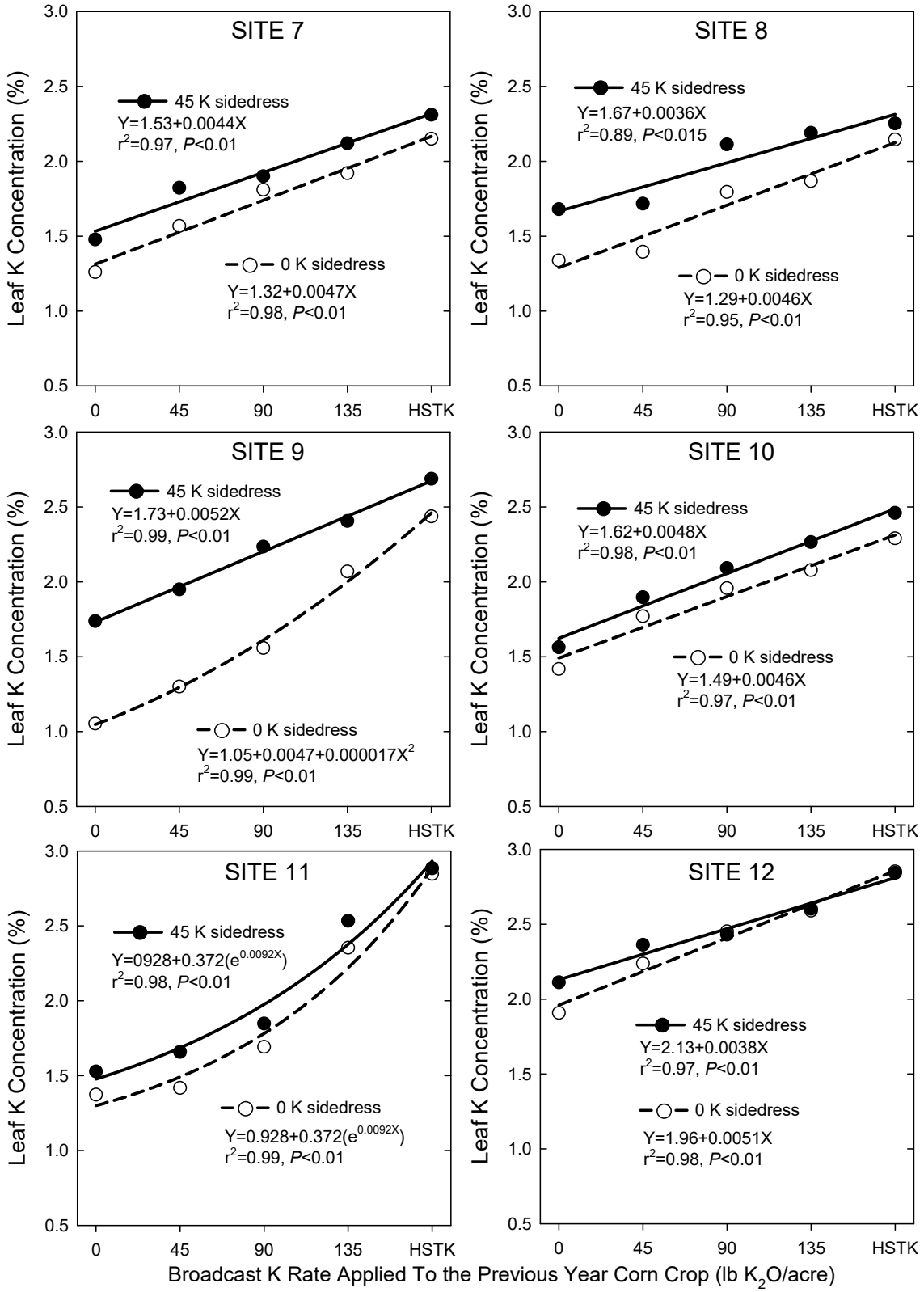

Fig. 7. Soybean trifoliate leaves K concentrations at the R2-R3 growth stages at six sites in 2019 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

Results for soybean grain K concentration in 2019.

Figure 8 shows that soybean grain K concentration responses to K were even smaller than for trials in 2018. The grain K increases to either broadcast K applied to the previous year corn or sidedressed K for both crops were large only at Site 11, which is surprising because STK levels were higher than at several other sites and the response cannot be explained with certainty. There were no statistically significant ($P \leq 0.05$ or ≤ 0.10) responses to K at Sites 8 and 12, which is reasonable only for Site 12 because STK was higher than at the other sites.

The sidedressed rate of 45 lb K_2O/acre attained maximum grain K concentration across all the treatments applied for the previous year corn crop at Sites 7, 8, and 12.

Results for K removed with soybean grain harvest in 2019.

Figure 9 shows that responses of K removed with soybean grain harvest differed across the sites. When sidedress K was not applied for either crop, there were differences ($P \leq 0.05$ or ≤ 0.10) among the treatments for the previous corn crop at all sites. The K removed increased up to a rate of 45 lb K_2O/acre broadcast before corn of the previous year at Sites 8 and 12 and linearly or exponentially to a maximum with rates of 135 lb K_2O/acre or the treatment with STK High or Very High before corn (HSTK). At Site 8, no continuous model fit the responses and means comparisons indicated low and similar removal for broadcast rates of 0 and 45 lb K_2O/acre and higher and similar removal for all other treatments before the previous year corn crop.

The sidedress K application resulted in statistically greater K removal ($P \leq 0.05$ or ≤ 0.10) compared with no sidedress application at all sites (Fig. 9) but differences were the larges for broadcast rates applied before corn of 90 lb K_2O/acre or less. The additional K removed increases were statistically significant up the previous year 45-lb rate at Sites 8 and 12, the 135-lb rate at Sites 7, 9, and 11; and up to HSTK treatment at Site 10.

Summary across trials conducted in 2019.

Table 7 shows average initial STK values for soybean across the six trials conducted in 2019 for each preplant treatment before corn but only for plots for which K sidedress was not applied.

Table 7. Average initial soil-test K for soybean across all sites conducted in 2019 as affected by broadcast K rates applied for the previous year (2018) corn crop.

Broadcast K	Dry STK†	Dry Category‡	Moist STK	Moist Category‡
lb K_2O/acre	-- ppm --		-- ppm --	
0	116	Very low	77	Low
45	126	VL-Low§	89	Low
90	143	Low	119	Optimum
135	166	Low	146	Optimum
HSTK⁋	211	Optimum	237	Very high

†Dry STK or Moist STK, average soil-test K by the ammonium-acetate and Mehlich-3 extractants using dry and moist testing procedures. ‡ Interpretation categories (Mallarino et al., 2023). § Value is borderline between two categories. ⁋ HSTK, treatment with High or Very High STK before corn that did not receive broadcast K for any crop.

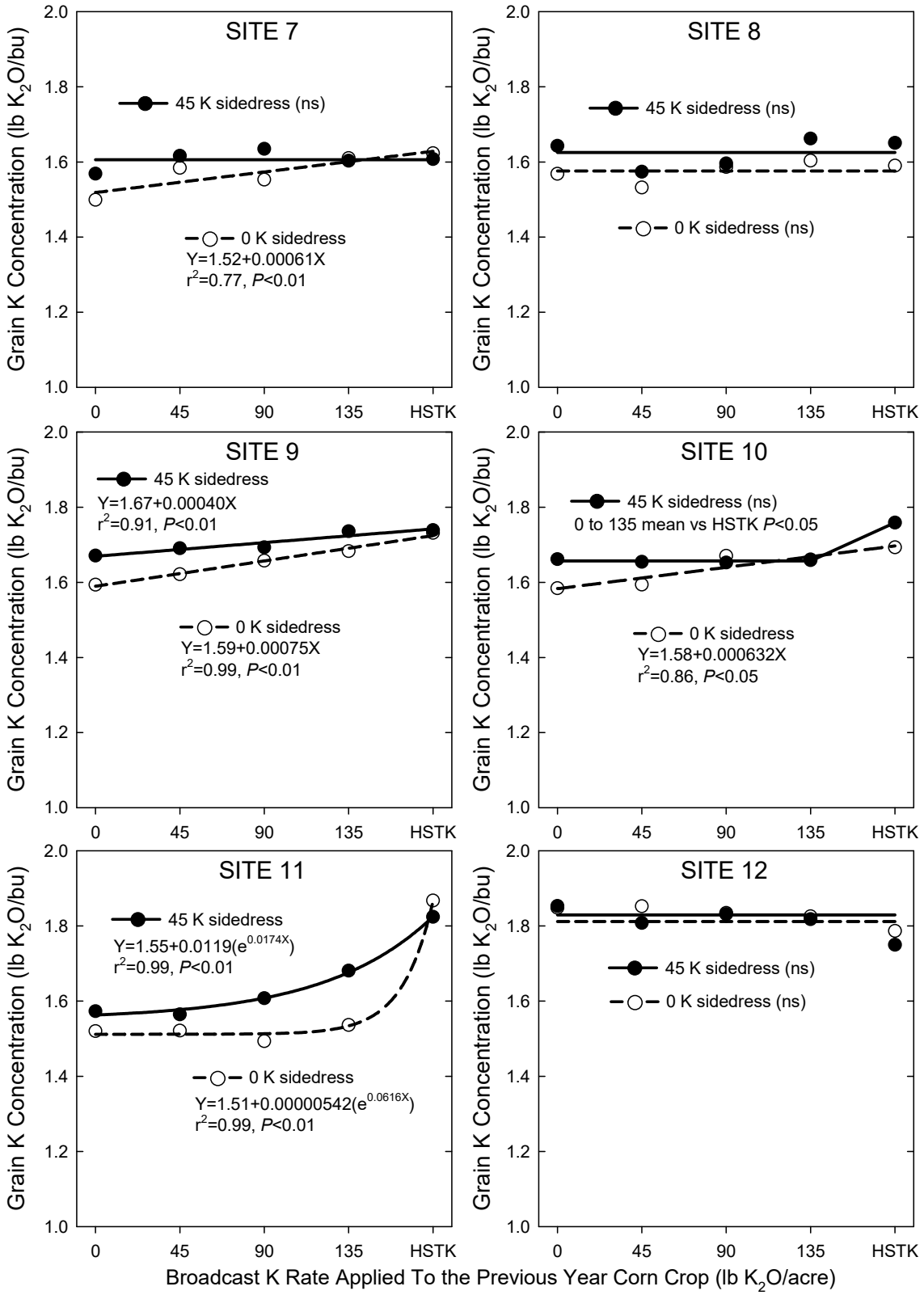

Fig. 8. Soybean grain K concentration at six sites in 2019 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

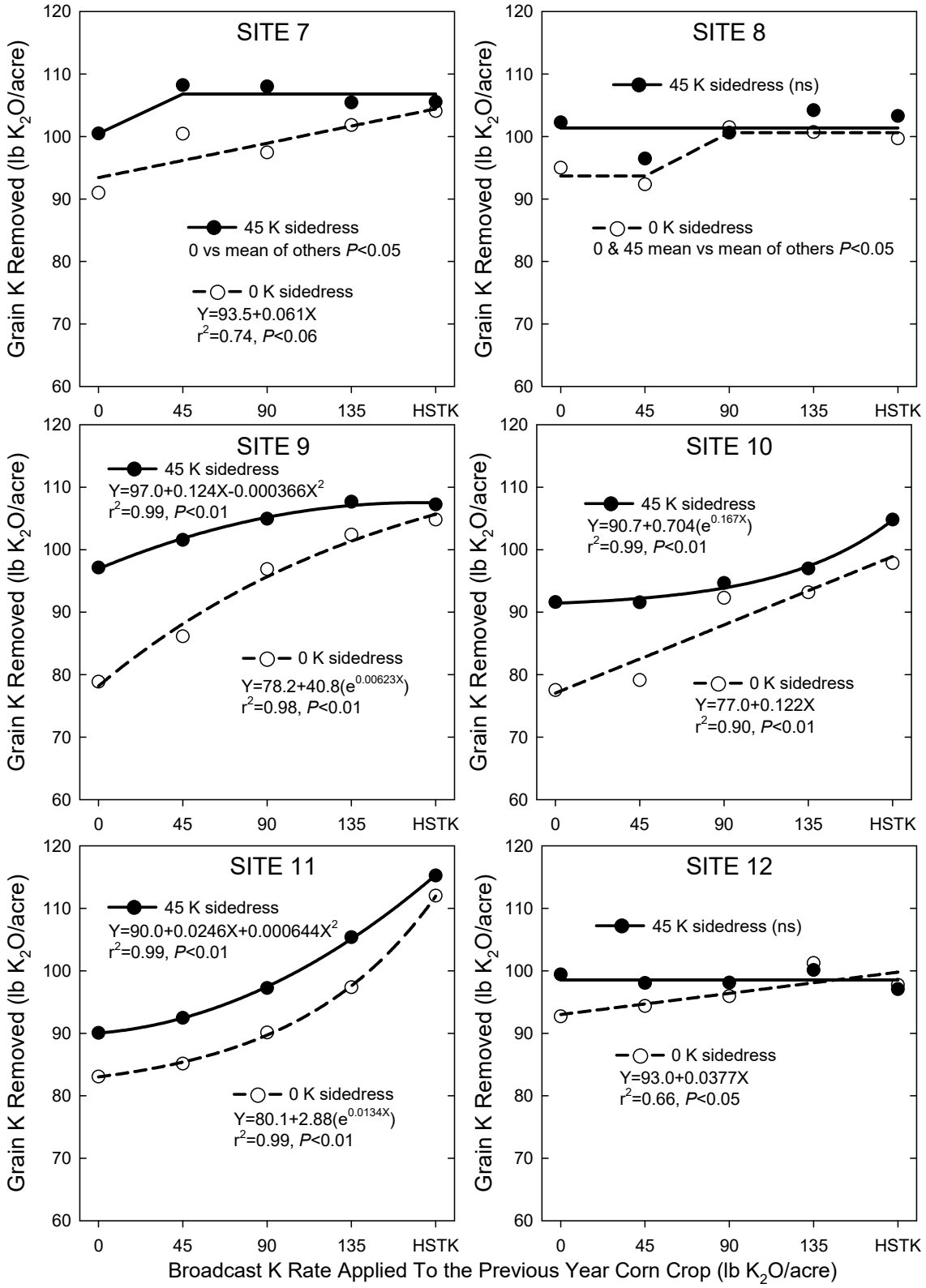

Fig. 9. Potassium removed with soybean harvest at six sites in 2019 as affected by broadcast K applied for the previous corn crop and K sidedressed for both crops. HSTK high-testing plots before corn that received no preplant K for either crop.

Dry STK (Table 7) was Very Low for broadcast rates before corn of 0 and 45 lb K_2O/acre, Low for rates of 90 and 135 K_2O/acre, and Optimum for the high-testing treatment before corn (no K applied to either crop). Moist STK was Low for broadcast rates before corn of 0 and 45 lb K_2O/acre, Optimum for rates of 90 and 135 lb K_2O/acre, and Very High for the high-testing treatment. As was discussed before, low STK for several treatments is reasonable since broadcast K rates before corn were lower than recommended for the 2-year rotation and the corn removed soil K and STK with dry or moist testing procedures often are not within the same categories.

Figure 10 summarizes the results for the six trials conducted in 2019 by showing average soybean grain yield, leaf K concentration, grain K concentration, and K removed with grain harvest across the trials. All soybean measurements increased as residual STK (Table 7) from treatments before corn increased.

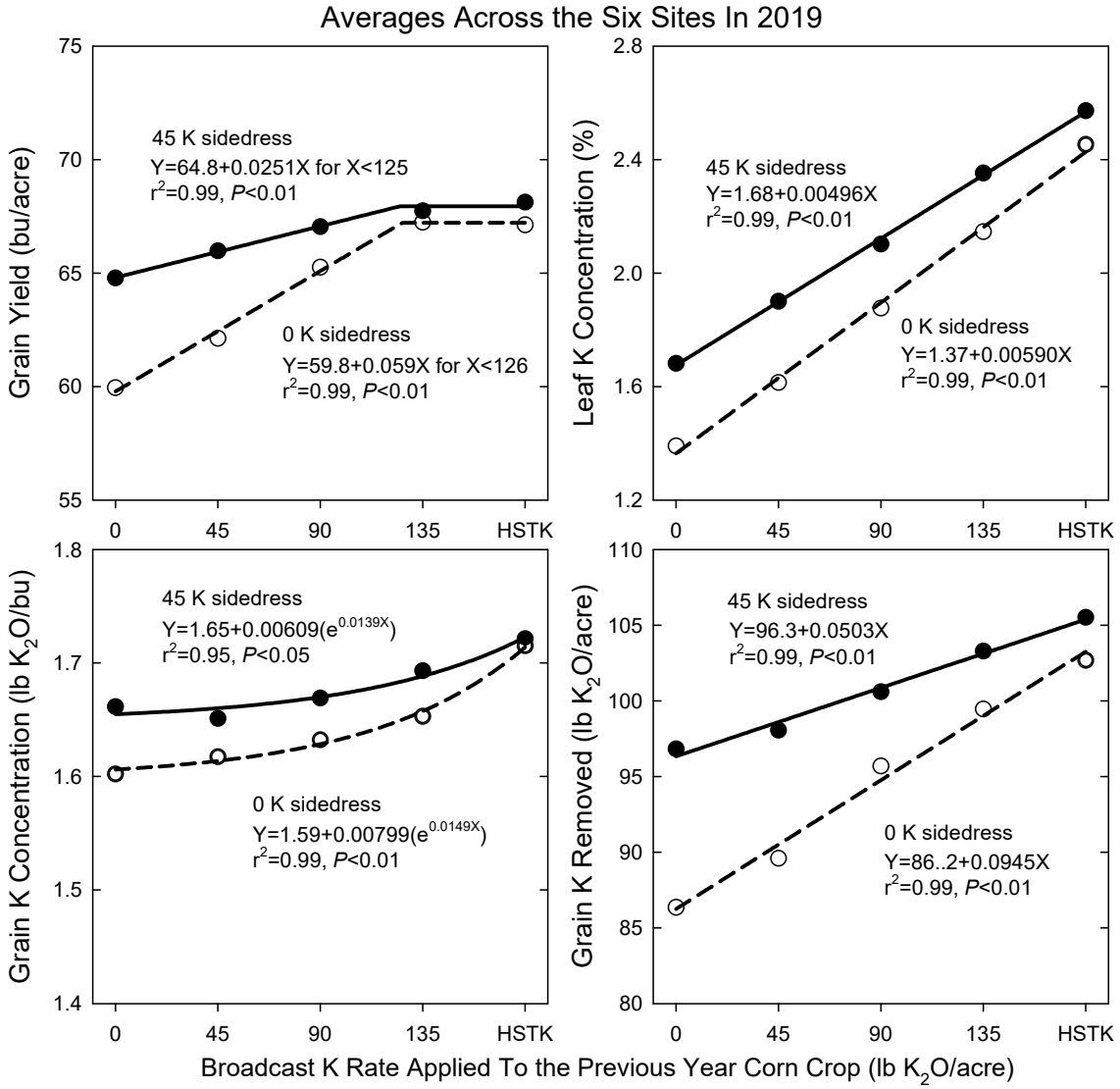

Fig. 10. Averages across six 2018 sites for soybean grain yield, trifoliate leaf K concentration, grain K concentration, and K removed with harvest as affected by treatments before the previous corn crop and fluid sidedressed K to both crops. HSTK = high-testing plots before corn (no preplant K for either crop.

Soybean grain yield responses in general was as expected for the observed average STK in Table 7. Without sidedressed K yield increased following a linear-plateau response up to a maximum of 67.5 bu/acre with an estimated rate before corn of 126 lb K_2O/acre (9 lb K_2O/acre less than the 135-lb rate).

With sidedressed K soybean yield also increased following a linear-plateau type response up to an estimated maximum of 68.0 bu/acre (statistically similar to the maximum yield without sidedress K) with an also essentially similar broadcast rate before corn of 125 lb K_2O/acre. Therefore, the additional yield increase with sidedressed K was statistically significant and large for broadcast rates before corn of 0 and 45 lb K_2O/acre (4 to 6 bu/acre) and small for the 90-lb rate (3 bu/acre) but not significant for the 135-lb rate or the HSTK treatment.

Figure 10 also shows that, as was observed for most sites in both years, the average response to K across sites of trifoliate leaf K concentration was proportionally the largest and the response to grain K concentration the lowest among the four crop measurements. There were large linear increases for leaf K concentrations and small exponential increases for grain K concentration with and without sidedressed K. The average response of K removed with grain harvest to broadcast K applied before corn and to sidedressed K was proportionally larger than the grain yield response because it combined increases in both grain yield and grain K concentration. The removed K increases were large and linear with and without sidedressed K, which contrasts to exponential increases with decreasing increments to a maximum observed for average K removed by trials conducted in 2018 (Fig. 5).

Summary and Conclusions

Soybean for this study was the second crop for 12 trials that began with corn the previous year. Broadcast K rates of 0, 45, 90, and 135 lb K_2O/acre had been applied before corn to four plots delineated on low-testing areas of each trial that across trials ranged from Very Low to Low in K by the dry or moist sample handling procedures. No broadcast K was applied before corn to a small high-testing area of each trial resulting from prior K applications. All plots at each trial were subdivided in late spring to sidedress 0 or 45 lb K_2O/acre at the V6 corn growth stage by injecting potassium-acetate fluid fertilizer in between the rows. No preplant K was broadcast for soybean but the same fluid K fertilizer treatments used for corn were applied to the same plots.

The soybean results showed a large residual effect of broadcast K treatments for the previous year corn crop as demonstrated by responses of grain yield, leaf K concentration, grain K concentration, and K removed with grain harvest. As previous K studies have shown, the response to K was proportionally the largest for leaf K, smallest for grain K concentration, and intermediate for both grain yield and K removed with grain harvest. Soil-test K by the dry or moist sample handling procedures before soybean at most sites ranged from Very Low to Low for corn preplant rates of 0 and 45 lb K_2O/acre, Low to Optimum for rates of 90 and 135 lb K_2O/acre, and Optimum to Very High for high-testing plots before corn that received no K.

Without K sidedressing, grain yield increased linearly or exponentially with decreasing increments to a maximum up to broadcast rates before corn of 90 or 135 lb K_2O/acre and the maximum yield did not differ from yield of high-testing plots before corn at any site. Observed

yield increases and STK levels were reasonable since broadcast rates before corn were lower than rates recommended for applying once the 2-year rate for the rotation.

The additional soybean grain yield increase from sidedressed fluid K fertilizer at 45 lb K_2O/acre compared with broadcast K treatments before corn varied greatly across sites. The additional yield increase from sidedressed K was small to large across sites being statistically significant with the Very Low or low STK resulting from no broadcast K before corn and at 11 sites when a 45-lb rate was broadcast before corn. The additional yield increase was statistically significant only at five sites for the 90-lb broadcast K rate before corn and only at one site for the 135-lb rate, and did not increase yield at any site for the high-testing plots before corn. Therefore, sidedressed fluid fertilizer increased soybean yield almost always when STK was Very Low to Low and sometimes when STK was Optimum. This result is reasonable because K fertilization is always recommended for these interpretation categories (only a removal-based rate is suggested for the Optimum category).

The sidedressed K resulted in additional leaf K concentration increases up to the 135-lb corn preplant rate at 11 sites and up to the high-testing treatment at five sites, which was expected due to known luxury uptake of K by vegetive crop tissue. However, additional increases from sidedressed K for grain K concentration were small and occurred mainly for the 0 and 45-lb corn broadcast rates. Additional increases for K removed for grain harvest tended to be larger and up to higher STK because it combined increases in both grain yield and grain K concentration.

Overall, the previous corn project showed that a broadcast preplant rate of 45 lb K_2O/acre increased corn grain yield more than a similar rate sidedressed at the V5-V6 growth stage by injecting liquid K fertilizer with very few exceptions. The results for this project for second-soybean showed that sidedressed fluid K fertilizer increased soybean grain yield only when soil K was deficient according to current Iowa State University soil test interpretations. Therefore, results from both corn and soybean do not support purposely withholding or reducing preplant K rates to be complemented by K sidedressing.

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