Uptake and Leaching Potential of Potassium and Sulfur When Split Applied for Corn On Irrigated Soil.

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Introduction

Soils with high amounts of sand face nutrient loss problems since water can freely move through the soil profile. Movement can be rapid for anions such as sulfate and may also present problems for cations such as potassium due to low cation exchange capacity. High yield potentials for corn (Zea mays L.) grown on irrigated sands have farmers questioning whether split applications of either nutrient should be considered to maintain availability through the growing season. The objectives of this study were 1) to use plant tissue analysis to determine whether split applications of potassium or sulfur are beneficial on irrigated corn and 2) to study the potential for leaching of K+ and SO_4^{2-} using lysimeters.

Materials and Methods

- Two field trials were conducted on irrigated soils for sulfur and potassium studies (Table 1)
- Treatments were arranged using a split plot design within a randomized complete block and were replicated four times. Main plots consisted of either sulfur or potassium applied at four rates and incorporated before planting. At approximately the V3 to V4 growth stage, main plots were split into four sub plots and the same rate of K or S were applied that were applied before planting.
- The K rates were 0, 72, 143, and 215 kg K ha^{-1}. Sulfur rates were 0, 14, 28, and 42 Kg S ha^{-1}.
- Nitrogen, phosphorus, potassium, and sulfur were applied when needed at non-limiting rates.
- At the V5 to V8 growth samples whole plants were sampled from both studies. Six plants were taken at random within each sub-plot. At R2, a total of 15 corn leaves were sampled from the leaf beside and below the ear.
- Plant samples were dried at 65ºC and ground to pass through a 2 mm sieve. Sulfur was determined using a Variomax CNS analyzer. Potassium was determined by ICP following wet digestion.
- Lysimeters were installed in plots receiving no fertilizer at planting or side-dress, no fertilizer at planting, and the high rate side-dress, the high rate at planting and no fertilizer side-dress, and the high rate and planting and at side-dress.
- Lysimeters were installed at a depth of 60 cm. Water was collected weekly through the growing season. Sulfate concentration in water was determined using ion chromatography. Potassium concentration was determined with ICP.
- Statistical analysis was conducted using PROC MIXED in SAS assuming fixed main effects (pre-plant and side-dress K and S rates) and random block effects for each location studied. For tables 2 through 5, means separation (LSD) was used when main effects were significant at $P \leq 0.10$. For leaching data, analysis was conducted assuming fixed main effects of sampling date, pre-plant, and side-dress fertilizer application.

Table 1. Plot Locations and Soil Properties for potassium and sulfur studies conducted in 2011.

				Soil Test 0-15cm†				
		Soil Type		P	K	S	pH	OM
Study	Site	Series	Classification	----mg kg^{-1}----				--g kg-1--
Potassium	Becker	Hubbard	Entic Hapludoll	15	42	--	5.4	1.1
	Randolph	Estherville	Typic Hapludoll	37	90	--	5.5	3.9
Sulfur	Hastings	Sparta	Entic Hapludoll	44	172	4.0	6.5	1.3
	Randolph	Estherville	Typic Hapludoll	31	83	3.3	5.3	2.8

† P, Bray-P1 phosphorus; pH, soil pH 1:1 soil:water; OM, LOI organic matter; S, mono-calcium phosphate S extraction.

Figure 1. Summary of potassium concentration in the soil water solution at a 60cm depth from the soil surface following application of 0 and 215 kg per K_2O /ha at-planting. Vertical bars indicate daily rainfall for each location. Asterisks indicate where main effects are significant.

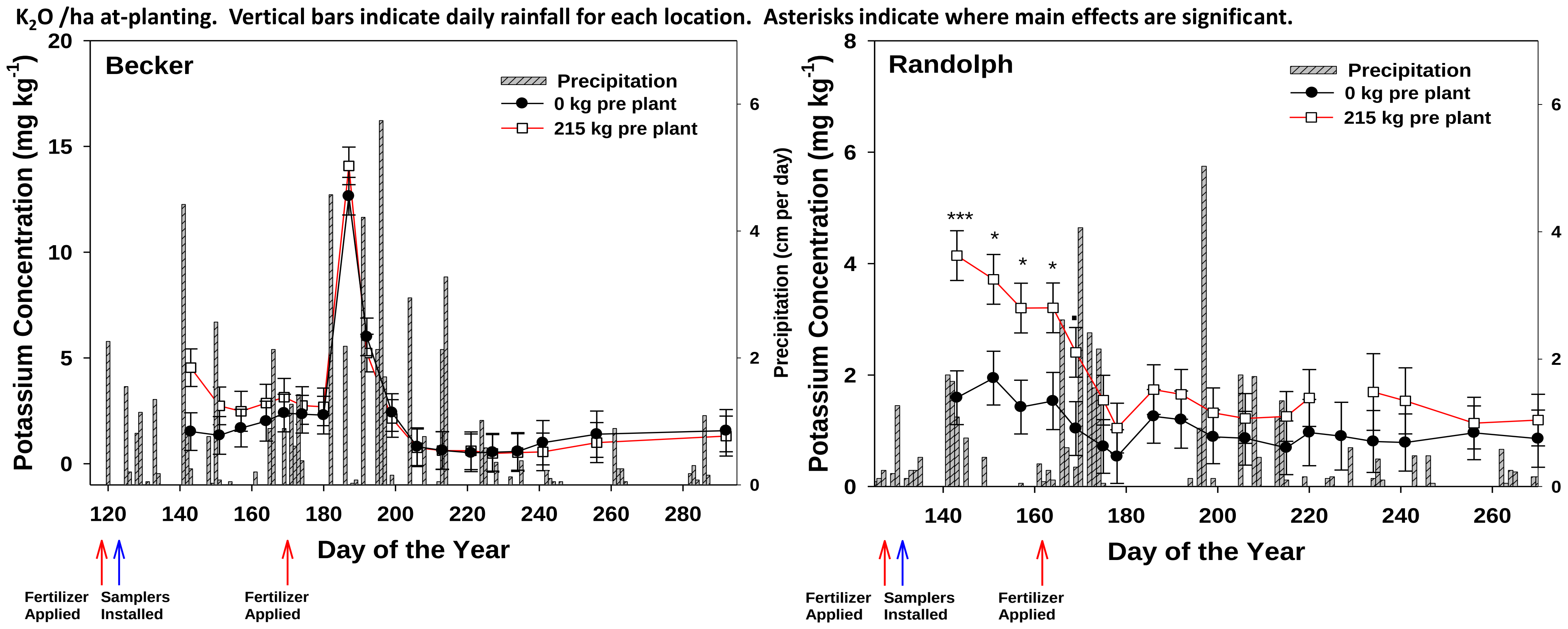

Figure 2. Summary of sulfate-sulfur concentration in the soil water solution at 60cm depth from the soil surface following application of 0 and 42 kg of S/ha at-planting and side dress combination. Vertical bars indicate daily rainfall for each location. Asterisks indicate where main effects are significant.

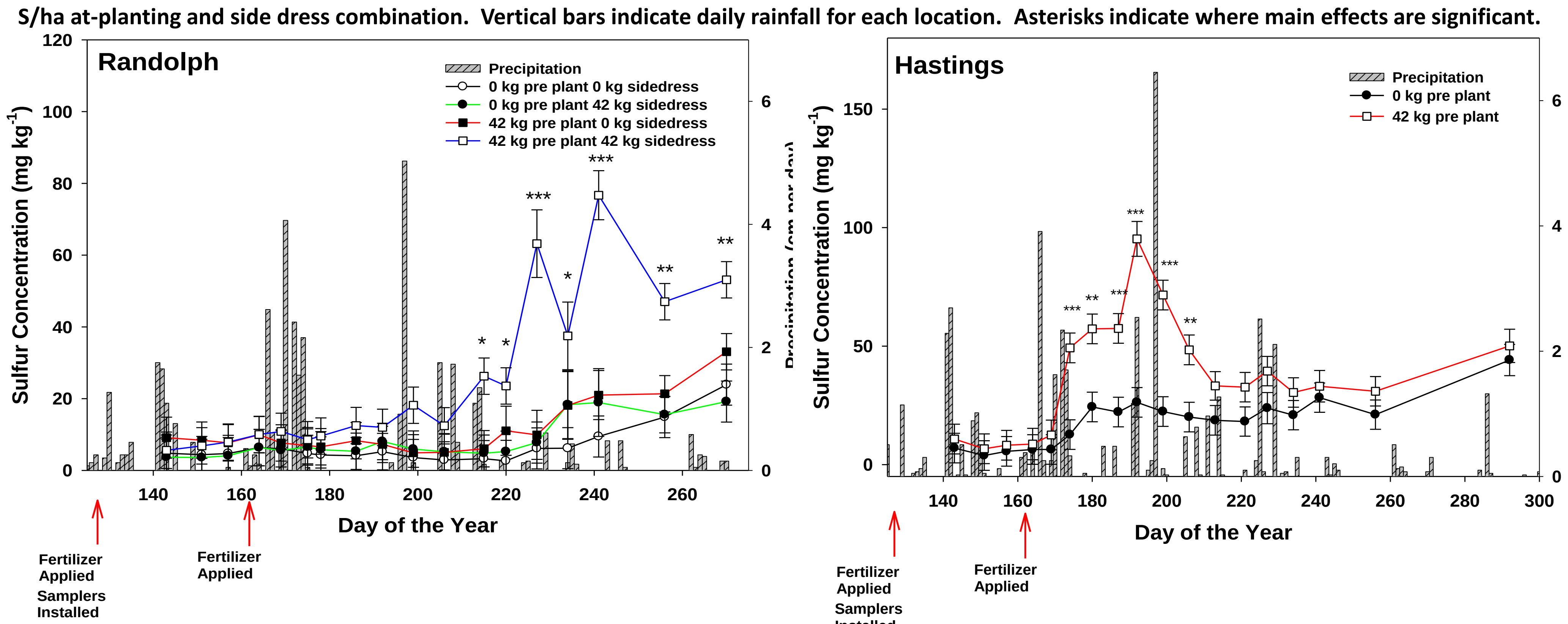

Table 2. Summary of average early plant uptake per plant of K for pre-plant and K side-dress treatments at two locations in 2011.

		Side Dress K Rate (kg K ha^{-1})				
	Pre-plant K	0	72	143	215	Mean
	kg K ha^{-1}	--------------mg K plant^{-1}--------------				
Becker	0	45	45	47	52	**47b**
	72	65	62	63	67	**64ab**
	143	90	89	76	94	**87a**
	215	78	79	102	71	**82a**
	Mean	70	69	72	71	
Randolph	0	456	469	464	484	468
	72	503	617	448	585	538
	143	531	532	580	646	572
	215	570	642	683	532	607
	Mean	515	565	544	562	

Table 3. Summary of average early plant uptake per plant of S for pre-plant and S side-dress treatments at two locations in 2011.

		Side Dress S Rate (kg S ha^{-1})				
	Pre-plant S	0	14	28	42	Mean
	kg S ha^{-1}	--------------mg S plant^{-1}--------------				
Hastings	0	8.7	8.7	7.5	8.2	**8.3b**
	14	10.5	11.0	9.7	11.0	**10.5a**
	28	11.2	11.6	11.8	12.3	**11.7a**
	42	11.4	11.5	11.3	10.9	**11.3a**
	Mean	10.4	10.7	10.1	10.6	
Randolph	0	31.6	31.7	32.7	39.1	33.8
	14	32.1	35.0	33.7	36.6	34.3
	28	32.8	39.3	35.2	35.6	35.7
	42	35.8	35.1	36.3	42.8	37.5
	Mean	**33.1b**	**35.3b**	**34.5b**	**38.5a**	

Table 4. Summary of ear leaf K concentration for pre-plant and side-dress potassium rates at two locations in 2011.

		Side Dress K Rate (kg K ha^{-1})				
	Pre-plant K	0	72	143	215	Mean
	kg K ha^{-1}	---------------g K Kg^{-1}---------------				
Becker	0	15.0	17.3	17.6	19.7	**17.4c**
	72	18.7	20.2	21.1	21.2	**20.3b**
	143	20.4	21.3	21.0	21.1	**21.0ba**
	215	20.7	21.3	21.8	22.5	**21.6a**
	Mean	**18.7a**	**20.0b**	**20.4bc**	**21.1c**	
Randolph	0	19.2	22.3	23.7	24.5	**22.4c**
	72	23.0	23.9	23.6	25.0	**23.9b**
	143	24.3	24.5	26.0	26.9	**25.4a**
	215	25.1	26.4	26.7	26.0	**26.0a**
	Mean	**22.9c**	**24.2b**	**2.5.0ba**	**25.6a**	

Table 5. Summary of ear leaf S concentration for pre-plant and side-dress sulfur rates at two locations in 2011.

		Side Dress S Rate (kg S ha^{-1})				
	Pre-plant S	0	14	28	42	Mean
	kg S ha^{-1}	---------------g S Kg^{-1}---------------				
Hastings	0	3.0	2.7	2.7	2.7	2.8
	14	3.0	2.9	2.8	2.9	2.9
	28	2.9	3.0	2.9	2.9	2.9
	42	2.8	2.9	2.8	2.8	2.8
	Mean	2.9	2.9	2.8	2.8	
Randolph	0	2.5	2.5	2.6	2.7	2.6
	14	2.4	2.5	2.6	2.8	2.6
	28	2.5	2.5	2.7	3.1	2.7
	42	2.5	2.8	2.9	3.0	2.8
	Mean	**2.5c**	**2.6c**	**2.7b**	**2.9a**	

Results and Discussion

- Early plant K uptake was significantly increased ($P \leq 0.10$) by pre-plant K at one location (Table 2). At Becker, the highest two K rates increased K uptake over the control. The 72 kg ha^{-1} rate was no different from the control or the higher rates.
- Early plant S uptake was significantly increased by pre-plant S at Hastings and side-dress S at Randolph (Table 3). At Hastings, all pre-plant S rates increased uptake over the control and there were no significant differences between rates. At Randolph, the highest side dress rate increased S uptake the most of any treatment which was followed by the 28 Kg ha^{-1} rate, while the 14 kg S ha^{-1} was no different from the control.
- Mid-season ear leaf samples showed significant differences of both pre-plant and side-dress K applications at both locations (Table 4). In general ear leaf K concentration increased with increasing rate of K applied both pre-plant and as a side dress. Statistical analysis found a significant interaction between pre-plant and side-dress K application at Becker (P=0.001) and Randolph (P=0.02) indicating that the effect of side-dress K was greater when no or low rates of K were applied pre-plant.
- Sulfur application affected mid season ear leaf S concentration at one location (Table 5). At Randolph, side-dress S significantly increased ear leaf S concentration. The 42 kg ha^{-1} application rate showed the greatest increase in S concentration followed by 28 kg ha^{-1} and the 14 kg ha^{-1} rate did not differ from the control
- There was no evidence of leaching of potassium as indicated by K concentration at 60 cm depth at the Becker location (Figure 1). Concentration did significantly differ by date (P<0.001) but there was no effect of pre-plant (P=0.60) or side-dress (P=0.77) K application at that location. At Randolph, the interaction was significant between pre-plant K application and date of sampling (P=0.007). When the interaction was sliced by date, the analysis indicated significant differences in K concentration at the first 5 sampling dates.
- Pre-plant S application significantly (P=0.001) affected S leaching at the Hastings location (Figure 2). Significant interactions between date and pre-plant S (P<0.001) indicated that the majority of the movement of S to the 60 cm depth occurred between the 6th to 11th sampling dates. At Randolph, both pre-plant (P=0.001) and side-dress (P=0.01) S significantly increased potential for S leaching. The three way interaction between Pre-plant S, side-dress S, and date was significant at this location (P=0.02). When factoring in date, movement of S was only detectable at the last seven sampling dates and increases in concentration were higher for 42 kg ha^{-1} pre-plant S + 42 kg ha-1 side dress S.

Conclusion

There was no evidence of a direct need for sulfur application at the locations studied. Mid-season plant sampling showed that K applied both pre-plant and as an early side-dress was available for corn. When measuring soil water K concentration at 60 cm, there was no direct evidence of movement of K to that depth at one location while concentrations were higher early in the season at another location. In contrast, increased concentrations of S were seen at both locations studied. Movement occurred more rapidly for the site where the soil was sandy compared to a loam soil where movement occurred later in the season. This data is the first year of a two-year project.

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