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Soybean Sudden Death Syndrome Influenced by Macronutrient Fertility on Irrigated Soybeans in a Corn/Soybean Rotation

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Abstract
The effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/ soybean cropping sequence were evaluated from 1983 to 2016, with corn planted in odd years. There was a negative relationship between the P rate applied during the corn years and the severity of sudden death syndrome (SDS) in 2014 and 2016 soybean.

Keywords
Sudden Death Syndrome, SDS, phosphorus, P, soybeans

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Summary
The effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 1983 to 2016, with corn planted in odd years. There was a negative relationship between the P rate applied during the corn years and the severity of sudden death syndrome (SDS) in 2014 and 2016 soybean.

Introduction
Sudden death syndrome (SDS) of soybean [*Glycine max* (L.) Merr], caused by *Fusarium virguliforme*, can cause significant yield loss in soybean, and has been associated with wet soils. Management practices to reduce yield losses have been to select tolerant varieties that are resistant to soybean cyst nematode (SCN), alleviate soil compaction, and delay planting to avoid wet soils. While these practices can reduce yield loss to SDS, significant losses can still occur.

A study was initiated in 1972 at the Topeka unit of the Kansas River Valley experiment field to evaluate the effects of N, P, and K on furrow-irrigated soybean. In 1983, the study was changed to a corn/soybean rotation with corn planted and fertilizer treatments applied in odd years. Study objectives were to evaluate the effects of N, P, and K applications on a corn crop on grain yield of corn, yield of the following soybean crop, and soil test values.

Procedures
The initial soil test in March 1972 on the silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 in. of the soil profile. Rates of P were 50 and 100 lb/a P_2O_5 (1972–1975), and 30 and 60 lb/a P_2O_5 (1976–2011); except in 1997 and 1998, when a starter of 120 lb/a of 10-34-0 (12 lb/a N + 41 lb/a P_2O_5) was applied to all plots of corn and soybean. Rates of K were 100 lb/a K_2O (1972–1975), 60 lb/a K_2O (1976–1995), and 150 lb/a K_2O (1997–2011). Nitrogen rates included a factorial arrangement of 0, 40, and 160 lb/a of preplant N (with single treatments of 80 and 240 lb/a N). The 40 lb/a N rate was changed to 120 lb/a N in 1997. Treatments of N, P, and K were applied every year to continuous soybean (1972–1982) and every other year (odd years) to corn (1983–1995, 1999–2013). Soil cores were pulled from each plot in

the spring of 2014, prior to planting. Analyses for macronutrients were performed from soil for each one-foot increment to a depth of four feet.

Soybean varieties planted in even years were: Douglas (1984); Sherman (1986, 1988, 1990, 1992, 1996, 1998); Edison (1994); IA 3010 (2000); Garst 399RR (2002); Stine 3982-4 (2004); Stine 4302-4 (2006); Midland 9A385 (2008); Asgrow 4005 (2010); Asgrow 3832 (2012); Asgrow 3833 (2014); and Asgrow 3731 (2016). Soybean was planted in early to mid-May. Herbicides were applied preplant each year, and postemergent herbicides were applied as needed. Plots were cultivated, furrowed, and furrow-irrigated through 2001 and sprinkler-irrigated with a linear move irrigation system from 2002 to 2016. In 2014, soil cores were collected from each plot at the 0-12-in. sampling depth prior to planting. The cores were then analyzed for soil test P, and the uppermost trifoliate leaflets were collected at R6 and analyzed for total P. Population densities (CFUs) of *F. virguliforme* were measured from post-harvest soil samples in 2014. The deep soil samples and trifoliate samples were only collected in 2014, while the disease ratings, normalized difference vegetation index (NDVI) , and yields were measured both years. In both years, percentage of leaf area infested by SDS was rated visually, and NDVI ratings were measured with a GreenSeeker meter (Trimble Navigation, Ag Division, Westminster, CO) at growth stage R6. Height to the top node with pods was measured at maturity (R8). A plot combine was used to harvest grain.

Results

The severity of foliar SDS symptoms in soybean was related to the rate of P applied to the corn in the corn/soybean rotation during previous years (Tables 1 and 2). The SDS was more severe, and the NDVI (measure of greenness), heights, and yields decreased as the rate of P decreased. The level of P in the soil was different at the different rates in a soil sample taken in the spring of 2014 (Table 3). The largest difference between P rates was in samples collected from the top foot of soil. There was no effect of N, K, nor any interactions of the three macronutrients with these four measurements (data not shown) in 2014. The level of P in leaf tissue decreased as the rate of P applied decreased. In 2016, the higher rates of N had less SDS and higher NDVI, but no difference in height or yield (data not shown). The average yield for the study in 2016 was greater than in 2014, 43.9 vs. 58.7 bu/a, respectively for 2014 and 2016.

Sudden death syndrome had not been observed to this degree in these plots in previous years. In addition, the effect of P on yield has not been this high. From 1984 to 2012, the average yield response from the check to the 60-lb rate was less than 6 bu/a. For 2014 and 2016, the average yield response to the 60-lb rate was 29 bu/a. Population densities (CFUs) of *F. virguliforme* were not significantly different between P levels, but tended to be greater with the decreasing levels of P (Table 1). The development of SDS in 2014 was probably related to the above-average rainfall in June of 8.26 in., which is 3.62 in. more than the 30-year average. The severity of SDS in 2016 was not as great as in 2014, with the average severity of 15% leaf area for 2016 compared 41% in 2014. The reduced severity of SDS may be related to the rainfall for June 2016, 2.73 inches, more than one inch below normal.

There was a very strong negative correlation between the foliar symptoms of SDS and NDVI for both years of the study (-0.79, <0.0001; Figure 1). The NDVI measurements are an objective measurement based on near-infrared light reflectance off the crop canopy, which can be affected by the greenness of leaves and density of the canopy, both of which can be influenced by multiple factors. Height of plants, development of branches, number and size of leaves, and amount of chlorophyll in leaves are some of the factors that can affect NDVI readings. The visual ratings of foliar symptoms tend to be more subjective but can focus on a single aspect of the crop health, in this case foliar symptoms of SDS. The strength of this correlation indicates that SDS was a primary factor affecting the health of this crop, even though height differences were related to P rates.

Yield of soybean correlated well with both the visual rating for SDS (-0.70, <0.0001) and NDVI (0.83, <0.0001) (Figures 2 and 3). This result suggests that SDS was a major factor affecting yield of soybean in this study. Combined with the strong relationship between the rate of P applied during the corn year of the rotation with yield and NDVI, the negative relationship with foliar symptoms of SDS indicates that P had a significant role in the severity of SDS and subsequent yield loss. To our knowledge, this relationship between P applied as a fertilizer and SDS has not been previously reported.

The consistency of the results from these two years further confirms the role P is having on the severity of SDS in this long-term fertility study. Even though the environments of both years were different, as well as the severity of disease and levels of yield, the relationships between P, SDS, and soybean productivity were very strong. These results enforce the importance of monitoring soil P levels in fields and increasing the soil P levels in fields with a history of SDS.

Table 1. Effects of phosphorus (P) applied to corn on sudden death syndrome (SDS) and yield of soybean, Kansas River Valley experiment fields, 2014

P rate on corn	*F. virguliforme*	Leaf phosphorus	SDS severity	NDVI[1]	Height	Yield
lb/a	CFU g^{-1} soil	parts per million	% foliage affected		in.	bu/a
0	70.8	0.15	58	0.758	29.8	34.0
30	62.5	0.18	43	0.777	36.0	44.8
60	41.7	0.26	23	0.799	37.0	52.9
LSD (0.05)	NS	0.01	16	0.018	2.2	4.3

[1]Normalized difference vegetation index.
LSD = least significant difference.
NS = not significant.

Table 2. Effects of phosphorus (P) applied to corn on sudden death syndrome (SDS) and yield of soybean, Kansas River Valley experiment fields, 2016

P rate on corn	SDS severity	NDVI[1]	Height	Yield
lb/a	% Foliage affected		in.	bu/a
0	20	0.796	34.6	46.4
30	17	0.803	39.5	60.1
60	8	0.810	41.6	69.5
LSD (0.05)	9	0.011	2.0	4.5

[1]Normalized difference vegetation index.
LSD = least significant difference.
NS = not significant.

Table 3. Soil test values for phosphorus (P) in macro-fertility study at Kansas River Valley experiment fields, 2014

P rate	1st Foot	2nd Foot	3rd Foot	4th Foot
	lb/a			
0	13	15	22	16.6
30	30	17.4	24.2	17.2
60	92	27.2	30.6	18.4
LSD (0.05)	8.8	1.9	2.7	NS

LSD = least significant difference.
NS = not significant.

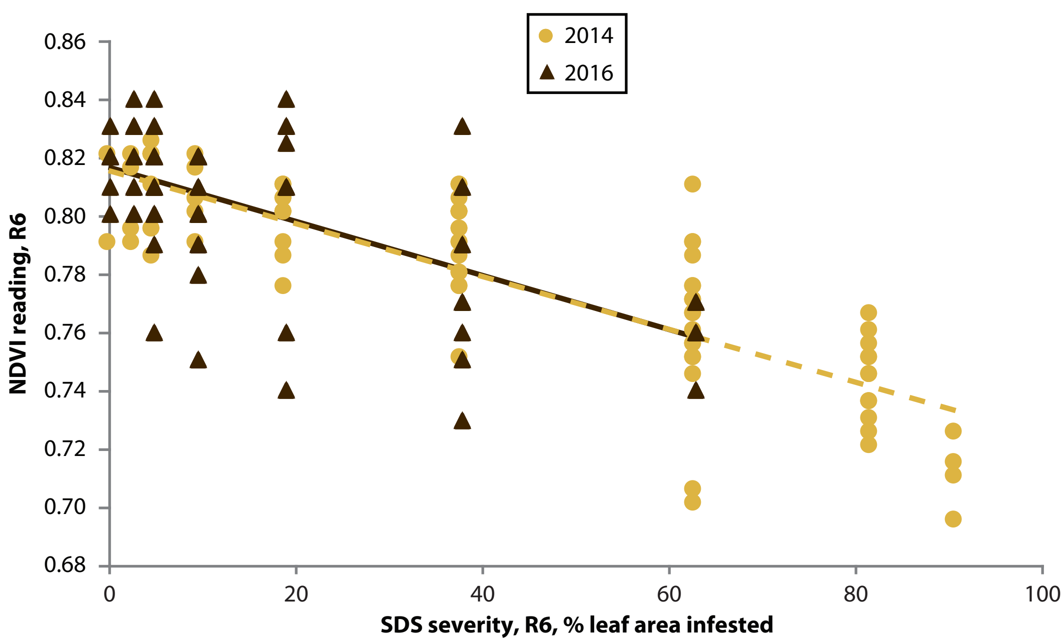

Figure 1. Relationship between visual ratings for severity of foliar symptoms of sudden death syndrome (SDS) and normalized difference vegetation index (NDVI) measurements with a GreenSeeker meter in a long-term macronutrient fertility study at the Kansas River Valley experiment fields, 2014 and 2016.

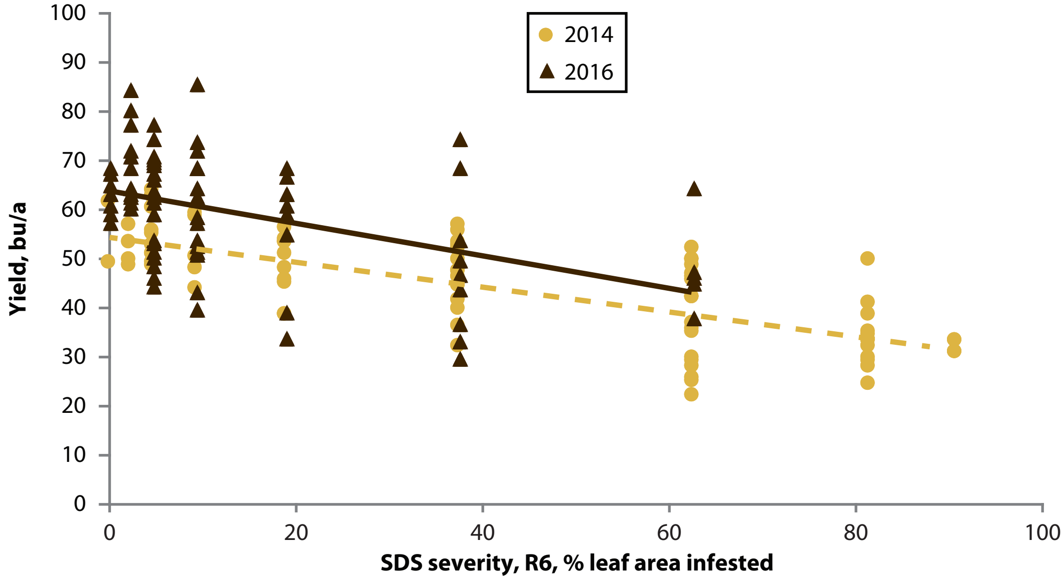

Figure 2. Relationship between foliar symptoms of sudden death syndrome (SDS) and yield of soybean at the Kansas River Valley experiment fields, 2014 and 2016.

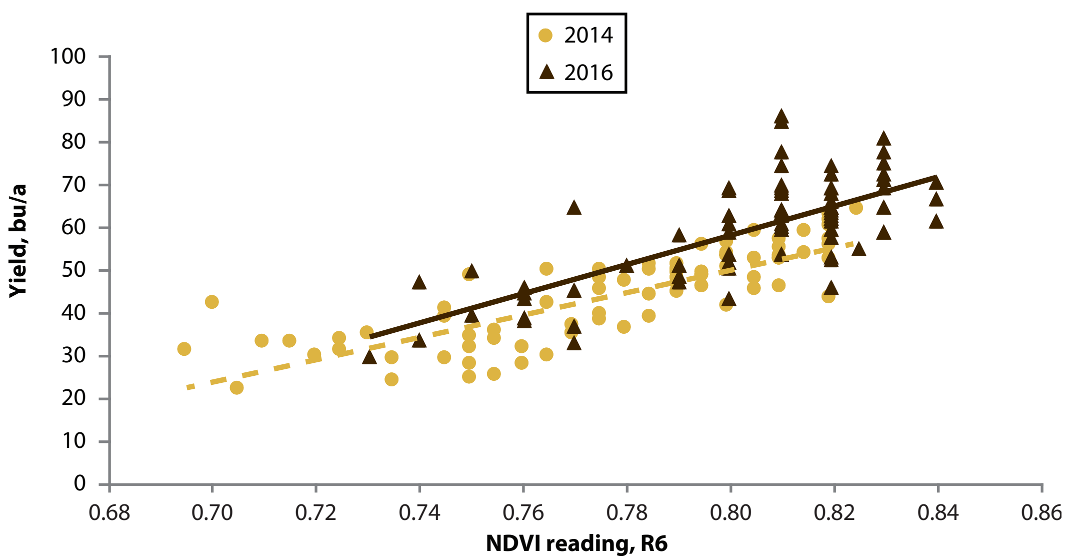

Figure 3. Relationship between normalized difference vegetation index (NDVI) and yield of soybean at the Kansas River Valley experiment fields, 2014 and 2016.