

Soybean Seed Yield Productivity and Biological Nitrogen Fixation in Kansas

L.F.A. Almeida, A.A. Correndo, E. Adee, S. Dooley, and I.A. Ciampitti

Summary

Soybean [*Glycine max* (L.) Merr.] productivity (seed yield) and biological nitrogen fixation (BNF) were evaluated in response to different fertilization strategies. The study comprised four different locations in Kansas during the 2021 growing season, two irrigated (Topeka and Scandia) and two dryland (Kiro and Ashland Bottoms) sites. Greater seed yields were recorded in Topeka and Kiro (80 bu/a) relative to Scandia (55 bu/a) and Ashland Bottoms (51 bu/a), without observing fertilizer effects on yields. Overall, the relative abundance of ureides (% RAU), an indicator of the level of BNF, increased as the crop matured and showed a negative association with the soil N level. The main objective of this study was to identify how different levels of nitrogen (N) and sulfur (S) fertilization affect the seed yield and the biological nitrogen fixation (BNF) in soybean.

Procedures

In the 2021 season, four soybean trials were established at Topeka (39°04'38.1" N, 95°46'05.4" W), Kiro (39°05'31.2" N, 95°47'50.4" W), Scandia (39°49'51.2" N, 97°50'22.8" W), and Ashland Bottoms (39°08'40.1" N, 96°37'42.6" W). The experiments were arranged under a randomized complete block design with five replications. Plot length was set to 50 feet in all the trials, width to 15 feet in both Kiro and Topeka, and 20 feet in both Scandia and Ashland Bottoms locations. Row spacing was 30 inches at all locations. The soil was tilled at Topeka, Kiro, and Ashland Bottoms. Planting dates ranged from mid to late May, and two genotypes were used (AG40X70 in Topeka and Kiro, and P39A45X in Scandia and Ashland Bottoms) (Table 1).

Weather

Topeka and Kiro accumulated approximately 23 inches of rain each during the growing season, while Ashland Bottoms had only 14.5, and Scandia had 12 inches. Both Topeka and Kiro locations had 6.2 inches after the first month, Scandia had 3.8 inches, and Ashland Bottoms only had 2.5 inches. Maximum temperatures higher than 95°F were reported during 19 days at Ashland Bottoms and 7 at Scandia. Between June and September, both Kiro and Topeka recorded 6 days with temperatures above 95°F (Figure 2).

Soil Fertility

Topeka and Kiro soils had considerably more clay and greater NO₃ and SO₄⁻² than the other two sites in both sampled depths. Soil organic matter (SOM) was also found in greater levels at Topeka and Kiro, respectively, 2 and 3% (Table 2).

Treatments

A total of five treatments were tested (Table 3): (1) a Check (0 N, 0 S); (2) an omission plot for S (N); (3) an omission plot for N (S), a low N rate combined with S (NS); and (4) a high rate of N combined with S (Full). Fertilizer sources, nutrient rates, and timing are described in Table 3.

Soil and Plant Sampling

A compound (6 cores) sampling at 0–6 inches depth was performed to describe initial fertility, and also 0–8 and 8–24 inches sampling was done to describe $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$, and $\text{SO}_4^{2-}\text{-S}$ prior planting. During the cropping season, additional soil samplings were collected at phenological stages of R2 (full-bloom), R4 (full-pod), and R6 (full-seed) (Fehr et al., 1971) at depths of 0–8 inches and 8–24 inches for all soil N and S determinations (Table 3).

Soybean tissue samples were collected as whole plants at the phenological stages of R2, R4, and R6 to measure biomass. Main stem samples were taken for the determination of relative abundance of ureide-N (RAU) (Moro et al., 2021). In early to mid-October, all the trials had the mid-rows cut by a combine, which provided seed yield adjusted to 13% in bushels per acre.

Data Analysis

Seed yield and relative abundance of ureides (RAU) were tested with an analysis of variance (ANOVA) under mixed effect models. For seed yield, treatment and site were considered as a fixed factor, and block as random. In the case of RAU, treatment, site, and stage are considered fixed, and blocks as random. When significant effects were found ($P \leq 0.05$), comparisons were performed using Tukey's test. Analysis was accomplished with R software (R Core Team, 2020) and packages lme4 and emmeans.

Results

Seed Yield

Soybean seed yield did not show an interaction nor fertilization effects ($P > 0.05$) but differed between sites. Topeka and Kiro yields reached 80 bu/a while Scandia and Ashland Bottoms yielded on average 55 and 51 bu/a, respectively (Figure 1). The abundance of water in the initial development of the soybean and greater soil fertility must have been the main drivers for the higher yields in Topeka and Kiro.

Relative Abundance of Ureides

The RAU did not show an interaction nor treatment effect ($P > 0.05$), but site and stage differed statistically. The treatment with the highest N input (300 lb/a), combined N fertilization with AMS and urea, was applied at planting and R3 stages, and even though not significant, it decreased RAU. The decay in this BNF activity occurred in R4 and R6 phenological stages, and compared to the other treatments, the decrease in ureide content in the xylem sap reflected in an RAU until 40% lower (Figure 3), emphasizing the effect of the mineral N in the N_2 fixation dynamics. From biomass, samplings were calculated as dry biomass per acre, and it has a positive correlation with crop growth during the season (data not shown).

Soil Nitrate and Sulfate

We observed a negative relationship between RAU and total N (nitrate-N + ammonium-N) in the soil, more evident for treatments where fertilizer was provided at a higher rate (Figure 4). According to soil results, sulfate levels were also related to greater RAU levels, but the main driver was N (with more soil N inversely related to N fixation).

References

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- R Core Team (2020). R: A Language and Environment for Statistical Computing. Available at: <https://www.r-project.org/>.

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Table 1. Site descriptors and crop management for the 2021 season

Site	Soil type	Tillage	Soybean variety	Seeding rate	Irrigation
				seeds/a	inches
Topeka	Eudora silt loam	Yes	AG40X70	140000	1.7
Kiro	Muir silt loam	Yes	AG40X70	140000	---
Scandia	Crete silt loam	No	P39A45X	140000	7.5
Ashland Bottoms	Eudora silt loam	Yes	P39A45X	130000	---

Table 2. Soil fertility at the planting time of soybean in the four locations across Kansas during the 2021 growing season

Site	Depth	pH	SOM	Sand	Silt	Clay	P	K	Depth	NO ₃	NH ₄	SO ₄ ⁻²
	inches			%			ppm		inches	ppm		
Topeka	0-6	6.77	2	32	56	12	16.7	227.9	0-8	6.1	4.9	3.6
									8-24	5	4.5	3.2
Kiro	0-6	5.49	3	16	62	22	27.3	419.7	0-8	8.9	6.8	5.3
									8-24	9.9	6.4	4.2
Scandia	0-6	7.5	1.2	46	42	12	46	186.4	0-8	3.1	3.1	2
									8-24	3.2	2.7	2.1
Ashland Bottoms	0-6	6	1.4	56	36	8	36.1	152.7	0-8	3.1	2.2	2.4
									8-24	2.1	1.87	1.8

SOM = Soil organic matter.

Table 3. Treatments description at planting time and R3 growth stage in Kansas during the 2021 season

Treatment	Planting			R3 growth stage			Total nutrients applied		
	N	S	Source	N	S	Source	N	S	
	----- lb/a -----								
Check	---	---	---	---	---	---	0	0	
N	26.3	---	Urea (58)	---	---	---	26.3	0	
S	---	30	Gypsum (130)	---	---	---	0	30	
NS	26.3	30	AMS (125)	---	---	---	26.3	30	
Full	150	15	Urea (297)	150	15	Urea (297)	300	30	
			AMS (64)			AMS (64)			

Check = no treatment applied.

N = an omission plot for S.

S = an omission plot for N.

NS = a low N rate combined with S.

Full = a high rate of N combined with S.

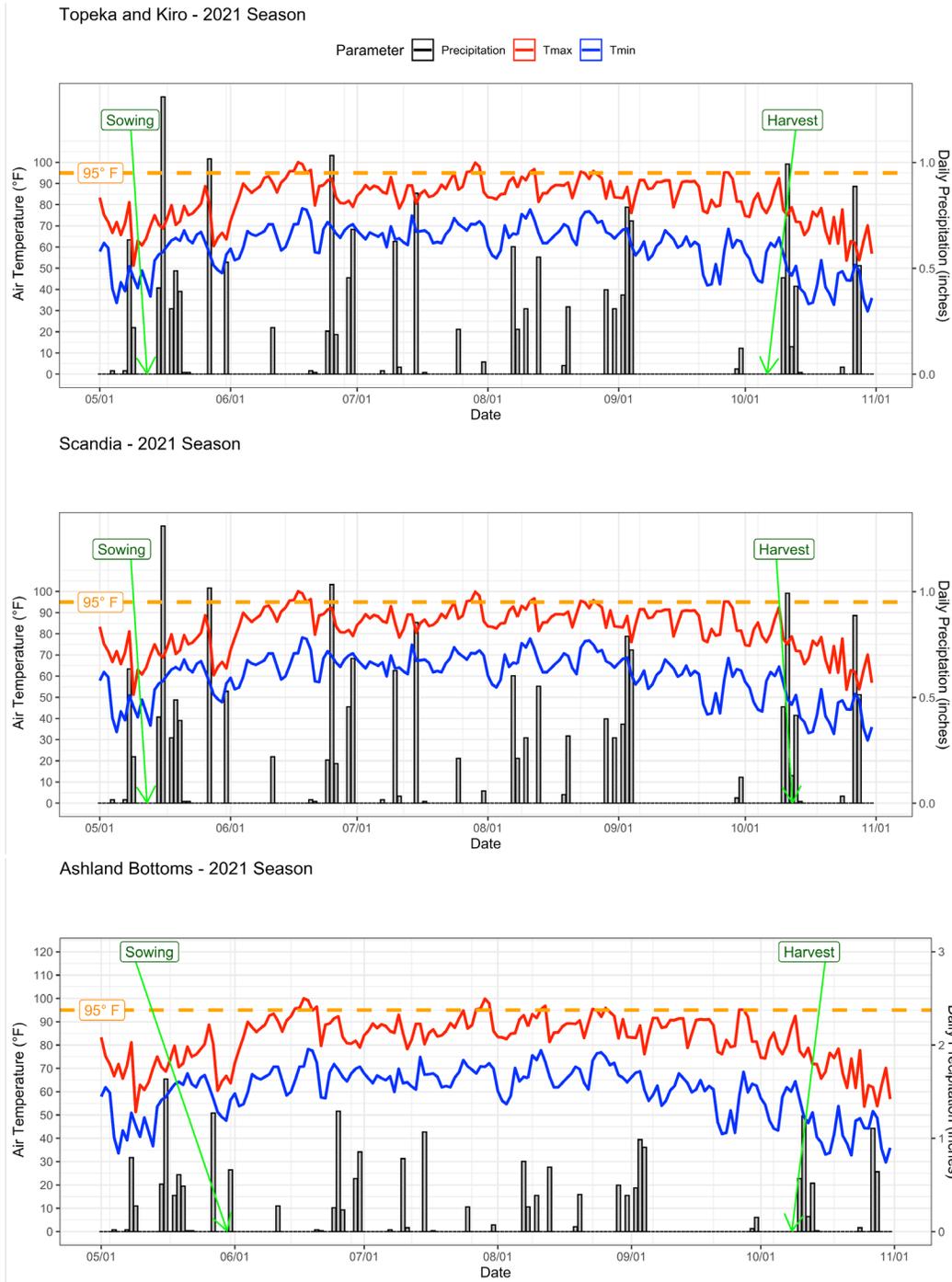


Figure 1. Daily precipitation in inches, and maximum and minimum temperatures (°F) for the 2021 growing season in Kansas, at three Mesonet weather stations.

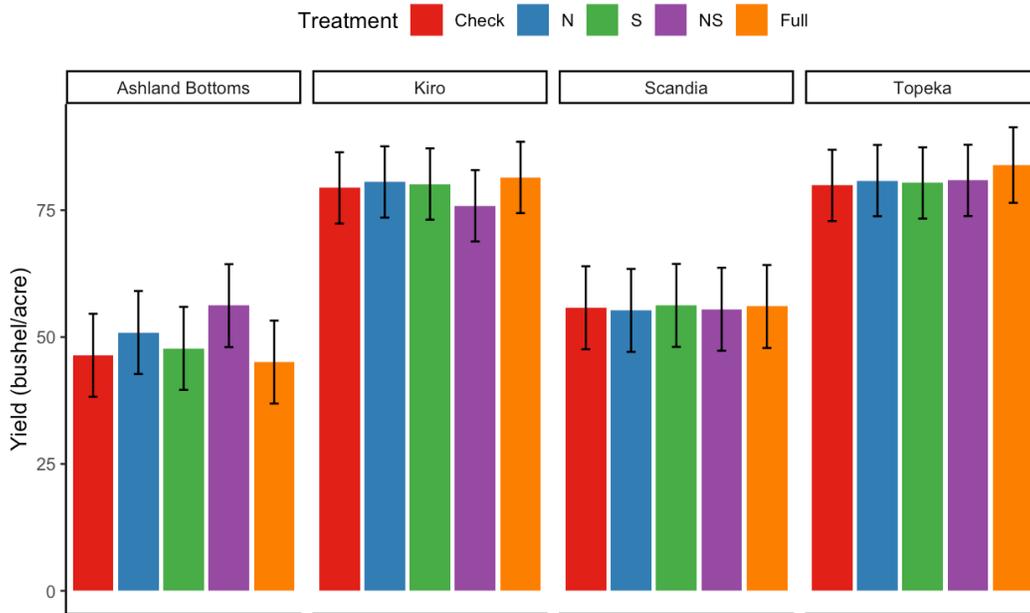


Figure 2. Soybean seed yield in bushel per acre across the 4 sites under study in Kansas during the 2021 season. Overlapping error bars indicate no statistical difference between treatments.

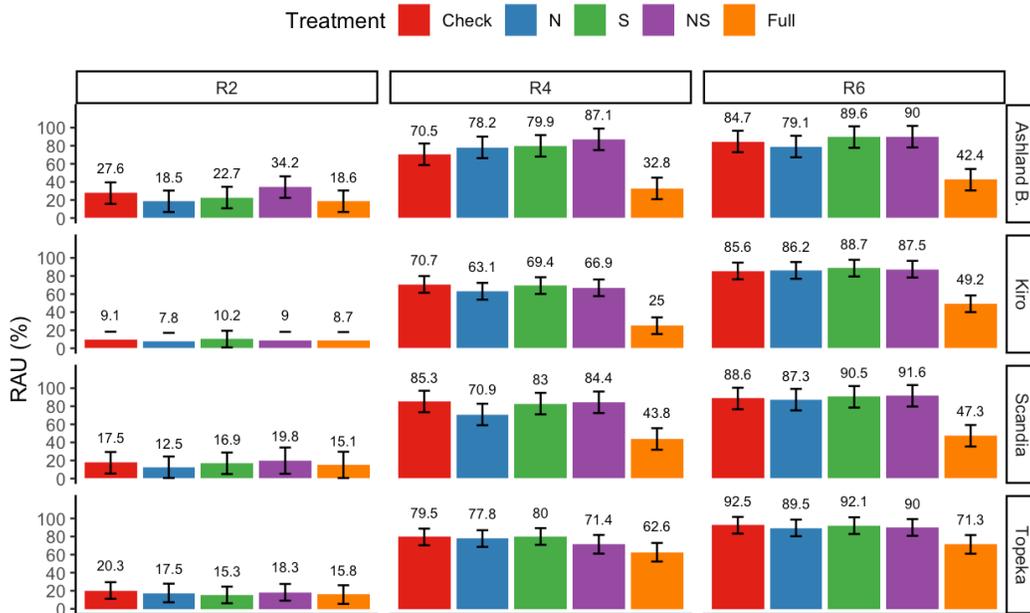


Figure 3. Relative abundance of ureides (% RAU) means being shown between treatments in 3 phenological stages at four sites in Kansas during the 2021 cropping season.

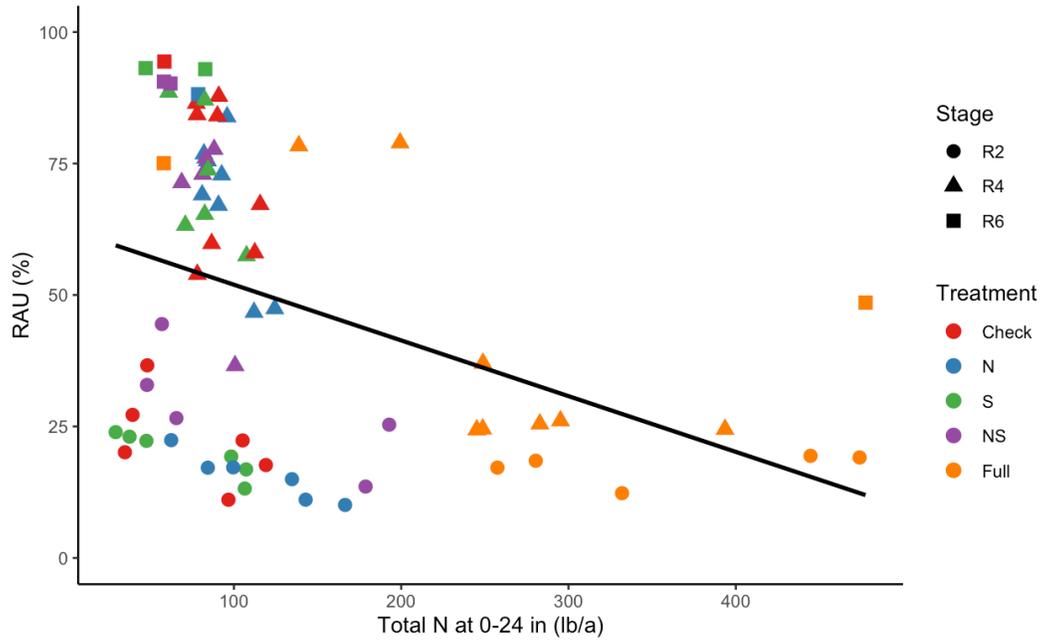


Figure 4. Total N (nitrate-N + ammonium-N, lb N/a) in the soil at 0–24 inches depth sampling for the 2021 season. RAU = Relative abundance of ureides.