Early Soybean Planting in a Water-Limited Growing Season

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Summary
Appropriate management, with a longer growing season during reproductive growth stages, can increase biomass and yield in soybean. Our objective was to determine the impact of three planting dates, two seed populations, and three maturity groups on grain yield in southeast Kansas. However, due to the severe drought in 2022, with a total rainfall of 18.84 inches during the soybean growing season (55% lower than the 10-yr average), the growing conditions were very limited, resulting in an average yield of 1.7 bu/a.

Introduction
Soybean (*Glycine max* (L.) Merr.) is one of the most important crop commodities in the U.S. Kansas has about 6% of the United States' soybean acreage. Soybean yield for 2022 totaled 132 million bushels, averaging 27.5 bushels per acre, which is down 12.5 bushels (31%) compared with 2021 (USDA, 2023). Several factors contribute to crop yield, including genetic traits, environmental conditions, and management practices. Thus, changing weather patterns across the United States have been stimulating researchers to re-examine how agronomic practices interact with the environmental conditions and impact yield.

Although soybeans can be planted at a wide range of dates, many research findings in neighboring Midwestern states have indicated that producers can profit from early planting dates. Though some studies have shown that the scale of the response to early planting can vary between years (Pedersen and Lauer, 2003), locations (Lueschen et al., 1992), and cultivars (Grau et al., 1994), more recent studies show a general trend of higher yields associated with earlier planting dates (Nleya et al., 2020). To explore that, our study was designed to understand the effect of planting date, plant population, and maturity group on yield in southeast Kansas.

Experimental Procedures
The trial was conducted at the Southeast Research and Extension Center in Parsons, KS, during the 2022 growing season. The soil was a Parsons silt loam, and 0- to 6-in.

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soil samples were collected in April 2021 (Table 1). According to Köppen, the local climate is classified as Cfa (warm, humid, hot summer). Weather data were recorded at a weather station located 1500 ft from the experimental site (Figure 1).
The experiment was established in a randomized complete block design with a factorial arrangement (planting dates vs. plant population vs. maturity group) with three replications. In each of the three planting dates [04/08/2022 (Early), 04/29/2022 (Middle), and 05/23/2022 (Late)], three soybean cultivars [maturity group (MG) 4.1, 4.7, and 5.4] were seeded at two target populations (100,000 and 150,000 seeds/acre). Each plot was composed of four 30-in. rows, for a total plot size of 10 ft wide × 40 ft long.

Soybean cultivars used in the study were 4121RXF/SR, 4720RXF/SR, and 5420RXF/SR, which are commonly grown by growers in southeast Kansas. Seeds were treated with the Acceleron Seed Applied Solutions (Standard) (a.i. pyraclostrobin, metalaxyl, fluxapyroxad, and imidacloprid). The seed treatment provides protection of root rot pathogens, including *Fusarium* spp., *Rhizoctonia solani*, *Pythium* spp., and *Phytophthora* spp.

The field was fertilized with 9 lb of N, 45 lb of P, and 45 lb of K per acre, using diammonium phosphate and potassium chloride, and cultivated on April 7. Post-emergent herbicide was applied on May 16, and plots were harvested on October 21, 2022.

Soybean growth stages (Fehr and Caviness, 1977) were determined in each plot 18 times throughout the growing season. Total aboveground biomass at V6 - R1 (6/13/2022), R2 - R3 (7/19/2022), R4 - R5 (8/15/2022), and R6 (9/12/2022) was collected in each plot, 1 linear m was randomly collected from the first or fourth rows. Samples were oven-dried at 60°F until constant weight and weighed.

Charcoal rot severity and *Macrophomina phaseolina* colony-forming units per gram of lower stem and roots (CFU/g) were assessed at the R7 stage, in 6 plants from each plot. Severity was reported on a scale from 1 to 5 (Paris et al., 2006). Colony-forming units (CFU) were calculated according to Mengistu et al. (2007). Dry samples were ground in a Wiley Mill Model ED-5 to pass through a 1-mm mesh screen. The mill was thoroughly cleaned between samples using a suction device. For each sample, 0.05 g of powdered tissue was placed in a microcentrifuge tube with 1 mL of 10% sodium hypochlorite (NaClO) and briefly vortexed. The tubes were shaken for 3 one-minute intervals with 15-second breaks in between and rinsed over a 45-µm pore size sieve with distilled water. The disinfected material was poured into a 50-mL falcon tube containing PDA medium that was previously autoclaved and amended with rifampicin (0.1 g/L) and tergitol (1 mL/L). After 3 days of incubation at 86°F, the CFUs were counted and converted to CFU per gram of ground tissue.

To determine grain yield, the two center rows were harvested in each plot after plants reached physiological maturity using a small plot combine (Gleaner K2). Grain yield was adjusted for 13% moisture. Immediately before harvesting, eight plants were taken from each plot to determine the number of pods per plant, the number of seeds per pod, and the 100-seed weight.

Biomass, charcoal rot severity, and *M. phaseolina* colony-forming units data were analyzed using the method of generalized linear mixed models (PROC GLIMMIX) in SAS. Biomass data were analyzed separately for V6 - R1, R2 - R3, R4 - R5, and R6. The means were estimated by least-squares mean (LSMEANS) and comparisons were performed using the probability of the difference (PDIFF) of the Student's t-test ($P < 0.05$). Test weight, grain yield, number of pods per plant, the number of seeds per pod, and 100-seed weights were not analyzed statistically due to the high variability resulting from the dry weather.

Results and Discussion

The days required to emerge were similar for the three planting dates, and there were no differences among varieties or plant populations (Table 2). The planting date affected the duration of the vegetative (VE to V6) and reproductive (R1 to R6) stages. Later planting dates resulted in a shorter period for each growth stage.

In 2022, the growing season was very dry and water stress limited plant growth (Figure 1). Total rainfall during the soybean growing season (April 8 to October 21, 2022) was 18.84 in., which is 55% lower than the average rainfall in the last 10 years (April to October). Plants were shorter, and the canopy did not close, reducing biomass. Soybean biomass was higher in the early planting dates when compared with middle and late dates during the whole season (Figure 2A). Only biomass at V6 - R1 was influenced by maturity group, population, and planting date × maturity group interaction. Greater biomass was observed in early planting, 5.4 MG, and 150,000 plants/a.

Because of the low disease pressure in this field, plant vascular tissue darkening (indicative of charcoal rot infection) was not observed. Tissues of the stem and root (inside and out) did not show high numbers of microsclerotia. However, the early planting date reduced charcoal rot severity compared with middle and late planting dates. The *M. phaseolina* colony forming units per gram at the lower stem and root did not differ for plant population, maturity group, or planting dates (Figures 2B and C).

Soybean grain yield is determined by the number of pods per plant, seeds per pod, and seed weight. However, most of the precipitation occurred prior to June 1 (Figure 1), before the reproductive stage, when floral abortion was intense in the field (R1-R2). After that, soil moisture remained very limited at the R3 and R4 growth stages, negatively impacting the number of pods, and drought at R5 and R6 reduced the number of seeds per pod and the seed size (Figure 3A, B, and C). Consequently, low test weight (53.8 lb/bu) and insignificant yield (1.7 bu/a) were registered in the 2022 growing season (Figure 3D).

Conclusion

Despite the early planting date presenting the greatest total biomass, number of pods per plant, and lower charcoal rot severity, soybean yield was not successfully assessed due to the weather conditions. Thus, the evaluation of planting dates, population density, and maturity groups cannot be conclusive due to the extreme drought conditions during the 2022 growing season in southeast Kansas. The trial will be repeated in 2023.

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Table 1. Soil chemical properties in the experimental area

pH	Mehlich-3 P	Extractable K	NH_4^+	NO_3^-	OM
	mg/kg				g/kg
5.7	16	95	1.6	25	3.1

Table 2. Total days from planting to emergence, duration of vegetative (VE to V6), and reproductive (R1 to R6) period in soybean

	Average number of days		
Planting date	Emergence	Vegetative period	Reproductive period
Early	13	42	85
Middle	11	35	72
Late	10	33	53

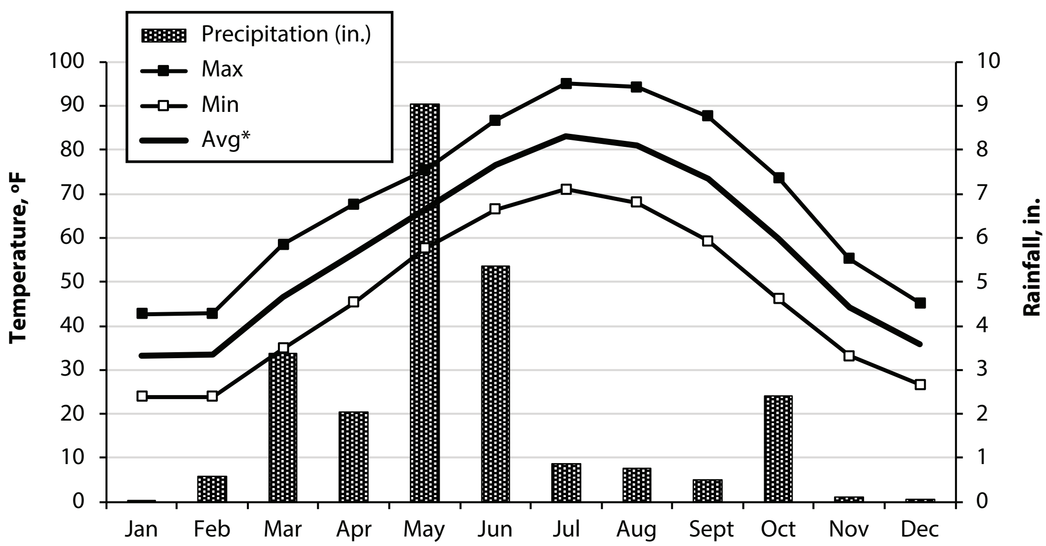

Figure 1. Monthly rainfall (in.), maximum, average, and minimum temperature (°F) in Parsons, KS, from January to December 2022.

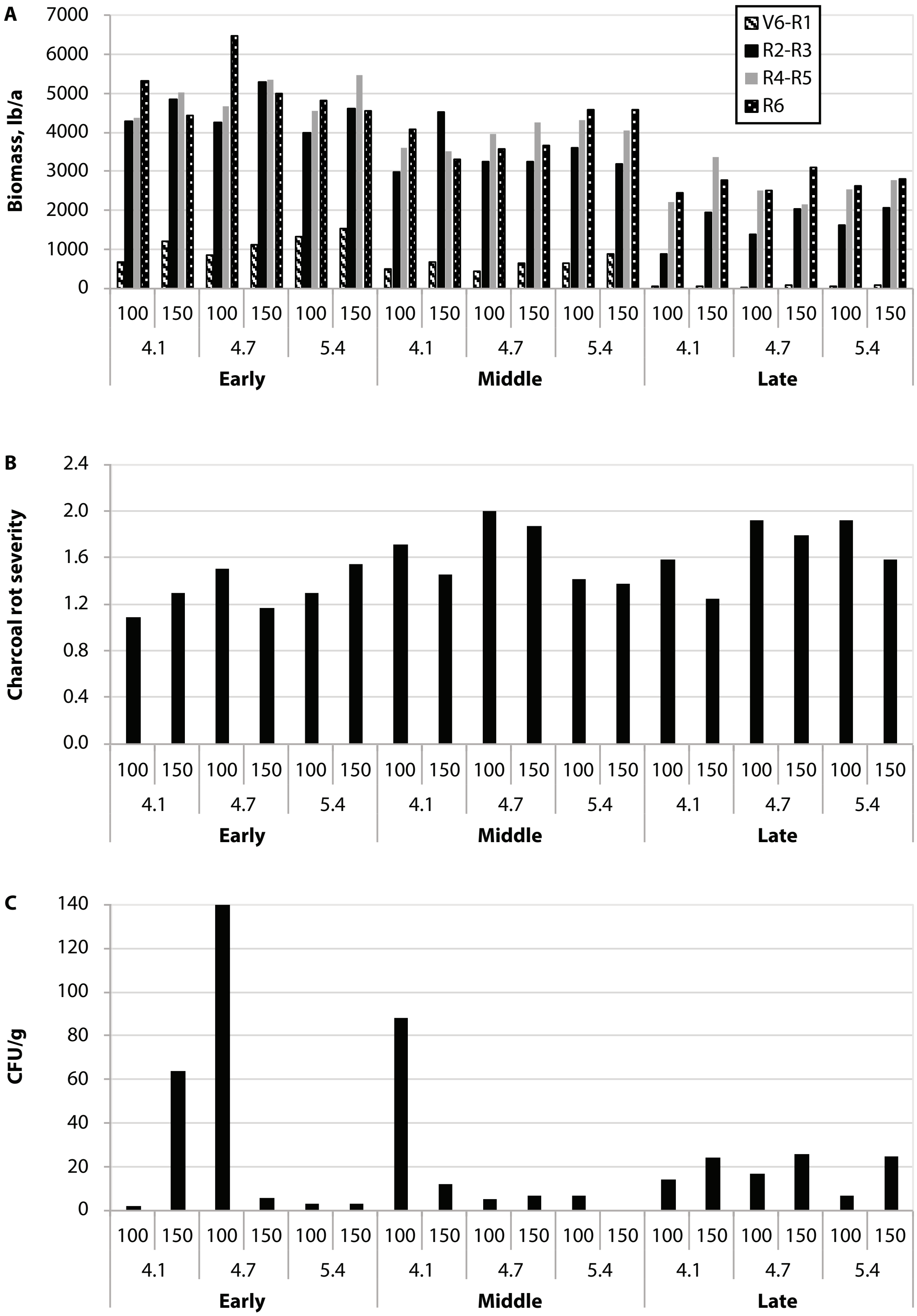

Figure 2. Biomass (A), charcoal rot severity (B), and *M. phaseolina* colony forming units (CFU) per gram (C) of two plant populations and three varieties at early, middle, and late planting dates.

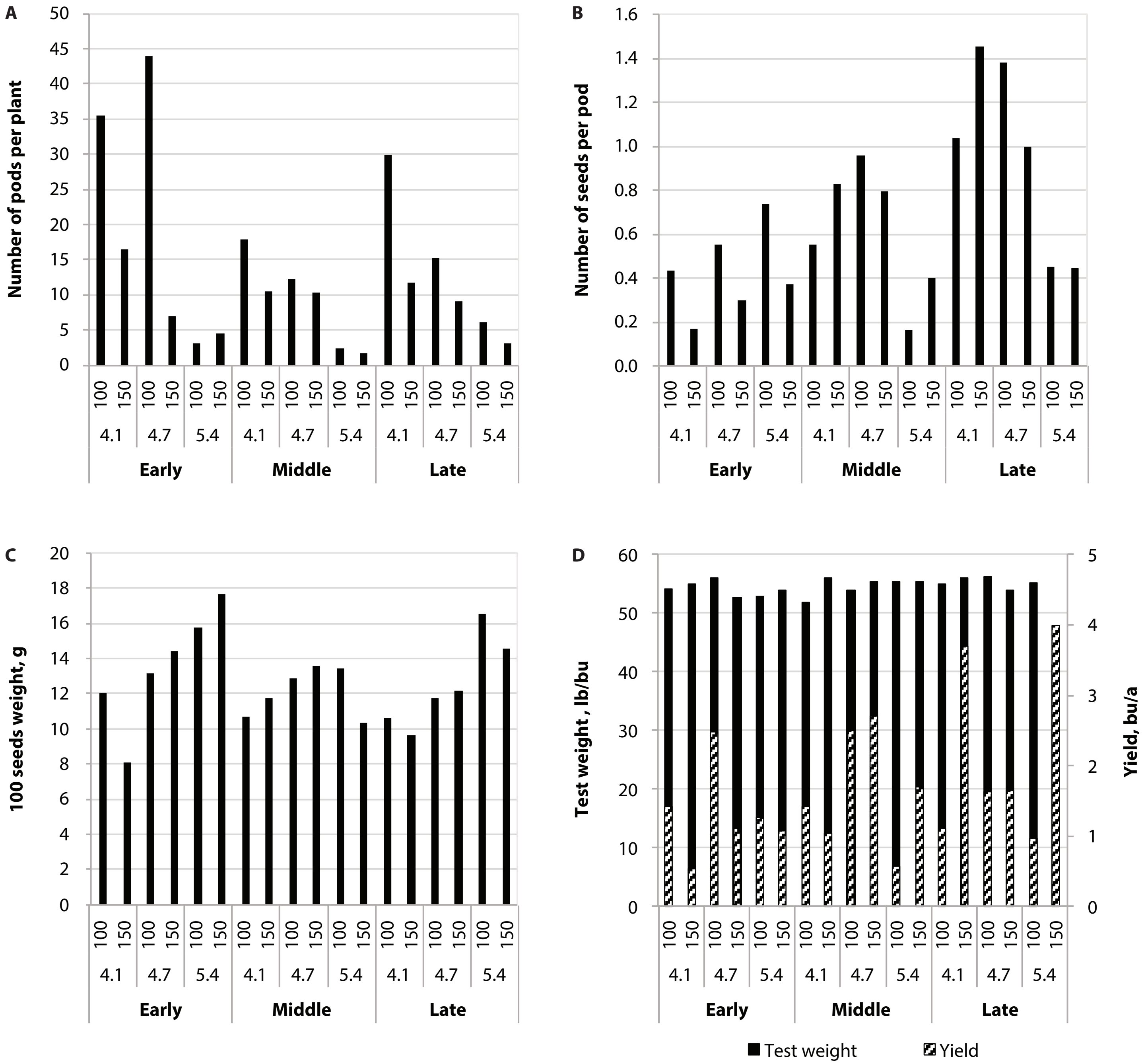

Figure 3. Number of pods per plant (A), number of seeds per pod (B), 100 seeds weight (C), and grain test weight and yield of soybean (D) of two plant populations and three maturity groups at early, middle, and late planting dates.