Does precision planting really matter in soybean?

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IN A BEAN POD:

- The interactive effect of seeding rate and seeding method is often ignored
- Precision method used a vacuum seed meter whereas the random method was cone-seeded
- Precision seeding resulted in more uniform spacing than random at the lowest seeding rate (40,000 seeds ac^{-1})
- Precision seeding increased seed yield compared to random at the lowest seeding rate (40,000 seeds ac^{-1})
- Precision planting can mitigate yield loss at sub-optimal seeding rates

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] production in the United States has occupied a yearly average of *c.a.* 82 million ac over the past decade with seed accounting for 13% of total production costs (USDA-ERS, 2019), or even higher for seed with different traits and seed treatments. With seed being a major cost of production, it is critical for growers to understand how soybean seeding rates affect their return on investment. While the effect of seeding rate on soybean yield, and its relationship to a multitude of management decisions, has been widely examined, there is limited research on the interaction of seeding rate with the impact of precision seed spacing.

With growers using lower seeding rates, planting has become an even more critical step in soybean production to ensure adequate stands. The fluted-roller seed metering system has been used on drills for over 300 years (*Jethro Tull - ASME*, n.d.). Although this metering system is still used today, it is sometimes referred to as "controlled spill" since it releases seed in bunches. As a result of the variable seed discharge, growers feel the need to increase seeding rates to ensure the whole field is seeded to the minimum desired rate (Ess et al., 2005).

Various soybean research has investigated the effects of between-row spacing (e.g., Cox & Cherney, 2011; Andrade et al., 2019); however, there is less exploration on the within-row spacing variation and its influence on soybean growth and yield. Due to the importance of seeding rate on the economic and agronomic management of soybean production, there is value in further investigating the potential advantages of decreased within-in row seed spacing variation. Thus, the objectives of this study were to determine (i) the effect of random and precision seed metering methods and (ii) the effect of exact seeding rates (seed spacing using hand planting) on soybean total and partitioned seed yield.

MATERIALS AND METHODS

Site characteristics

Two field experiments were established, both in 2019 and 2020, at the University of WI Arlington Agricultural Research Station in Arlington, WI (89.3450174°W, 43.3030601°N) which has a humid continental climate. Temperature and precipitation values were obtained from the Arlington Agriculture Research Station. The study sites were in a long-term corn-soybean rotation. Planting occurred on 23 May 2019 and 7 May 2020 at a depth of 1-inch. Sites were managed using conventional tillage.

Seed metering method comparison study

Treatments for this study were arranged in a split-plot randomized complete block design with four replicates and consisted of 28 combinations of two seed metering methods (precision vs. random), two cultivars (Asgrow AG20X9 and Asgrow AG25X9, Acceleron seed treatment) and 7 planting densities (40,000, 60,000, 80,000, 100,000, 120,000, 140,000, and 160,000 seeds ac^{-1}). Seed metering method was the main plot factor, and cultivar and planting density were completely randomized within the split-plot. Soybean cultivars used were resistant to glyphosate and chosen based on their high yield potential. The precision metering method was accomplished using a four row, 30-inch spacing, mounted John Deere 1705 planter equipped with a vacuum seed meter and soybean seed plate. Seeding rates were controlled using the system monitor and RTK corrected GPS position data. The random treatments were planted using a custom built, four-row, 30-inch spacing, plot planter equipped with a cone seed distribution system and John Deere row units similar to those in the precision metering treatment. Seed was counted and packeted prior to planting.

Canopy coverage was quantified at R1 (first flower) (Fehr and Caviness, 1977) and 7 and 16 days after R1. In 2019 initial canopy coverage measurements began 16 July and in 2020 initial measurements began 7 July. To determine grain yield, the center two rows from all plots were harvested after plant maturity with an Almaco SPC40 plot combine (Almaco, Nevada, IA). Grain weight and moisture were recorded and yield was converted to bu ac^{-1} and adjusted to moisture content of 13%. Plant-to-plant spacing measurements were determined at the V2 growth stage each year to allow for adequate time for all viable seeds to emerge.

Plant architecture study

Treatments for this study were arranged in a randomized complete block design with four replicates and consisted of four planting densities (50,000, 80,000, 110,000, and 140,000 seeds ac^{-1}). Soybean cultivar Asgrow AG20X9 was used based on its high yield potential. The seeding rate treatments were hand planted in 15-inch rows using a seed spacing guide to assure accurate seeding density. Rows with 100% counted emergence were selected after maturity for hand cutting of plants at the soil surface. Plant samples were counted and individually separated into branches, main stems, branch pods, and main stem pods. Then, pods were threshed to reveal seed number and weight. Each trait parameter was divided by the number of plants in the sample to determine the value on a per plant basis. Branch and stem seed yields were determined mathematically by multiplying their weight by the treatment seeding rates. Total yield was the sum of the calculated branch and stem yield.

RESULTS

Seed yield

Across the two years of the study, the interaction between seeding method and seeding rate significantly affected seed yield ($P < 0.001$). Seeding rates of 80,000 to 160,000 seeds ac^{-1} for precision method and 100,000 to 160,000 seeds ac^{-1} for random method resulted in similar yields (Table 1). The lowest seeding rate (40,000 seeds ac^{-1}) was the only rate where random seeding method yielded 12 bu ac^{-1} less than precision seeding (18% difference).

Table 1. Effects of seed metering method and seeding rate on soybean seed yield across 2019 and 2020.

Seeding rate seeds ac^{-1}	Seed metering method: Precision	Seed metering method: Random	‡Pr > F
	-------------bu ac^{-1}-------------		
160,000	79a†	81a	0.456
140,000	77ab	81a	0.116
120,000	78a	78ab	0.974
100,000	75ab	76ab	0.499
80,000	74ab	73bc	0.583
60,000	70b	68c	0.425
40,000	70b	58d	<.001

†Values followed by the same letter within each seed metering method (within column in the table) are not significantly different at α = 0.05.
‡Probability of a larger F by chance between levels of seed metering method for the same seeding rate (within row in the table).

Table 2. Effects of seeding rate and cultivar on soybean seed yield across 2019 and 2020.

Seeding rate seeds ac^{-1}	Cultivar: AG20X9	Cultivar: AG25X9	‡Pr > F
	-------------bu ac^{-1}-------------		
160,000	83a†	77ab	0.035
140,000	79abc	79a	0.974
120,000	79ab	76ab	0.231
100,000	74bcd	78a	0.054
80,000	72cd	76ab	0.102
60,000	68de	71bc	0.261
40,000	63e	64c	0.777

†Values followed by the same letter within each cultivar (within column in the table) are not significantly different at α = 0.05.
‡Probability of a larger F by chance between levels of cultivar for the same seeding rate (within row in the table).

Random planting

Precision planting

A variable response to seeding rate, independent from seeding method, was observed between the two cultivars (P=0.041). For both cultivars, greatest yield was observed with high seeding rates (Table 2). The greatest yield for the early maturity cultivar (AG20X9) was observed for seeding rates greater than 100,000 seeds ac^{-1} whereas, greatest yield for the later maturity cultivar (AG25X9) was observed for seeding rates greater than 80,000 seeds ac^{-1} (Table 2). A yield difference between the two cultivars was observed only for the highest seeding rate where AG20X9 resulted in 7% greater yield than AG25X9.

Plant population

Across the two years of the study, seeding method and seeding rate significantly affected plant population (P=0.021 and P<0.001, respectively). Precision seeding resulted in *c.a.* 3,500 plants ac^{-1} lower than the random method across all seeding rates (Table 3). Additionally, plant population varied due to variable seeding rates. Approximately 66 to 81% of planted seeds resulted to viable plants with greater attrition (as % of seeding rate) at the lower seeding rates. However, no significant interaction between seeding method and seeding rate was observed. These results do not explain the observed yield difference between the two examined seeding methods at the lowest seeding rate.

Table 3. Effect of seed metering method and seeding rate on plant population and attrition across 2019 and 2020.

Seed metering method	Plants ac^{-1}
Precision	67,000 a†
Random	70,500 b

Seeding rate (seeds ac^{-1})	Plants ac^{-1}	Attrition (seeding rate-plant population as plants ac^{-1})	Attrition (as % of seeding rate)
160,000	118,600 a	40,255	25.8
140,000	107,000 b	32,930	23.5
120,000	95,940 c	23,900	19.9
100,000	81,560 d	18,440	18.4
80,000	63,850 e	16,310	20.3
60,000	42,900 f	17,000	28.4
40,000	26,530 g	13,550	33.8

†Values followed by the same letter are not significantly different at $\alpha = 0.05$.

Within row plant-to-plant spacing

Across the two years of the study, the interaction between seeding method and seeding rate significantly affected within-row plant spacing (P=0.035). For both methods, plant-to-plant spacing was greater for the low seeding rates (Table 4). The range of average plant-to-plant spacing between the greatest and lowest seeding rates was narrower for the precision method (1.5 inch) when compared to the random method (2.7 inch). However, within each seeding rate, plant-to-plant spacing differences were inconsistent between the two methods. The largest difference was observed for the lowest seeding rate (40,000 seeds ac^{-1}) where precision planting resulted in more uniform within-row plant spacing. Presumably, this could have contributed to the greater yield in the lowest seeding rate due to precision planting when compared to random.

Table 4. Effects of seed metering method and seeding rate on within-row mean (standard error) plant-to-plant space (inch) across 2019 and 2020.

Seeding rate seeds ac^{-1}	Seed metering method: Precision	Seed metering method: Random	‡Pr > F
	------------------inch	------------------	
160,000	1.7 (0.19)c†	1.5 (0.26)d†	0.259
140,000	2.1 (0.26)bc	1.7 (0.06)dc	0.048
120,000	1.6 (0.09)c	1.7 (0.08)dc	0.704
100,000	1.9 (0.24)bc	2.2 (0.11)bc	0.161
80,000	2.8 (0.26)a	2.9 (0.11)b	0.814
60,000	2.6 (0.31)ab	2.7 (0.14)b	0.557
40,000	3.2 (0.33)a	4.2 (0.4)a	0.010

†Values followed by the same letter within each seed metering method (within column in the table) are not significantly different at $\alpha = 0.05$.
‡Probability of a larger F by chance between levels of seed metering method for the same seeding rate (within row in the table).

Canopy closure

Across the two years of the study and regardless of measurement date, canopy closure between the two seeding methods (P=0.004) and between the two cultivars (P=0.013) varied among the tested seeding rates. During the first 16 days after R1, on average, precision planting resulted in greater canopy closure in all seeding rates apart from 100,000 and 160,000 seeds ac^{-1} (Figure 1). For the same period, the average canopy closure for the AG20X9 cultivar was greater for all seeding rates when compared to the AG25X9 cultivar apart from the 100,000 seeds ac^{-1} seeding rate where the difference was not significant (Figure 2). These results suggest that regardless of measurement day after R1, seeding rate interacted with cultivar and seeding method and affected the average percent of canopy closure. Especially for seeding method, the greatest canopy closure difference was observed in the lower seeding rate (Figure 1) which could have also contributed to the greater seed yield for precision seeding at 40,000 seeds ac^{-1}.

Figure 1. Percent canopy closure, across R1 (first flower) + 16 days, as affected by the interaction between seeding method and seeding rate across 2019 and 2020. Seeding method canopy closure estimates with the same letter within each seeding rate are not significantly different at alpha=0.05. Error bars show the standard error of the mean.

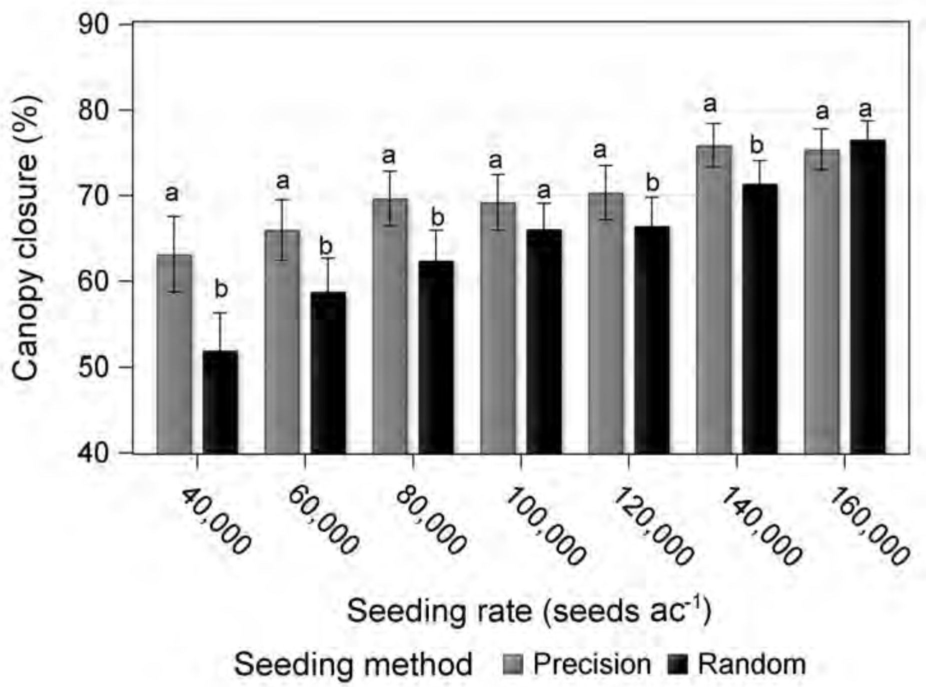


Figure 2. Percent canopy closure, across R1 (first flower) + 16 days, as affected by the interaction between cultivar and seeding rate across 2019 and 2020. Cultivar canopy closure estimates with the same letter within each seeding rate are not significantly different at alpha=0.05. Error bars show the standard error of the mean.

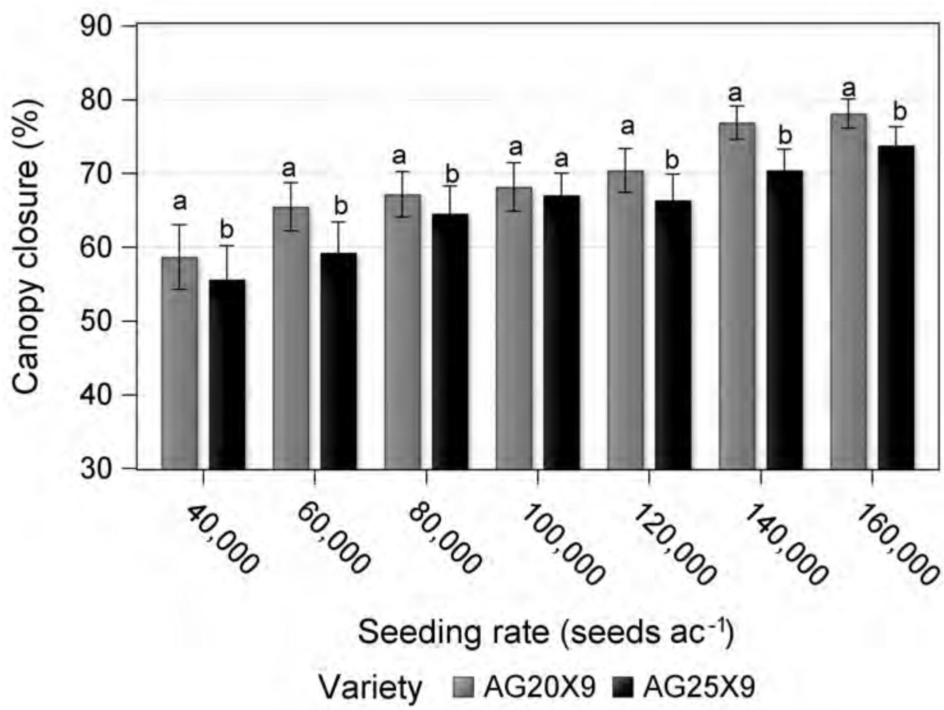


Figure 3. Percent canopy closure, between R1 (first flower) and R1 + 16 days, as affected by random and precision seeding method across 2019 and 2020. Seeding method canopy closure estimates with the same letter within each day after R1 are not significantly different at alpha=0.05. Error bars show the standard error of the mean.

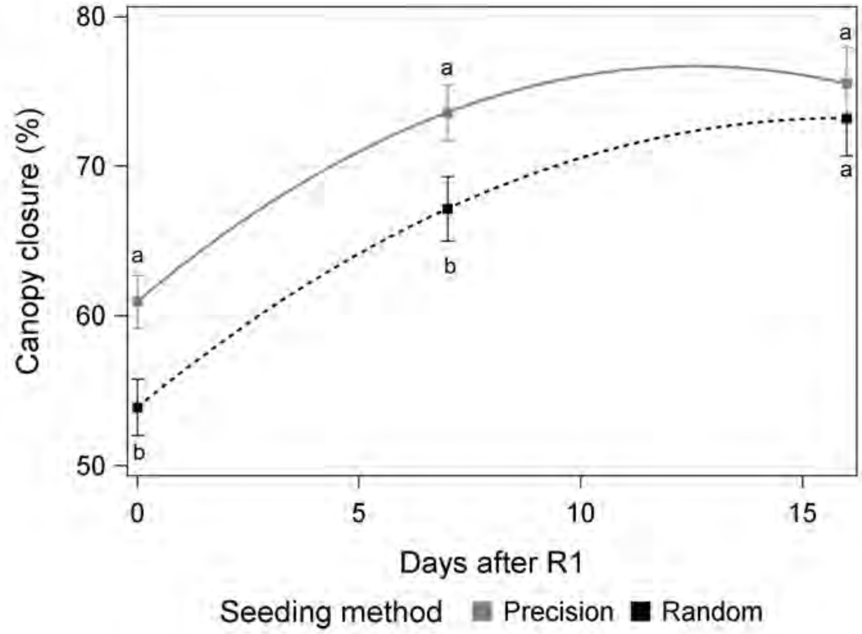


Figure 4. Percent canopy closure, between R1 (first flower) and R1 + 16 days, as affected by two cultivars (AG20X9 and AG25X9) across 2019 and 2020. Cultivar canopy closure estimates with the same letter within each day after R1 are not significantly different at alpha=0.05. Error bars show the standard error of the mean.

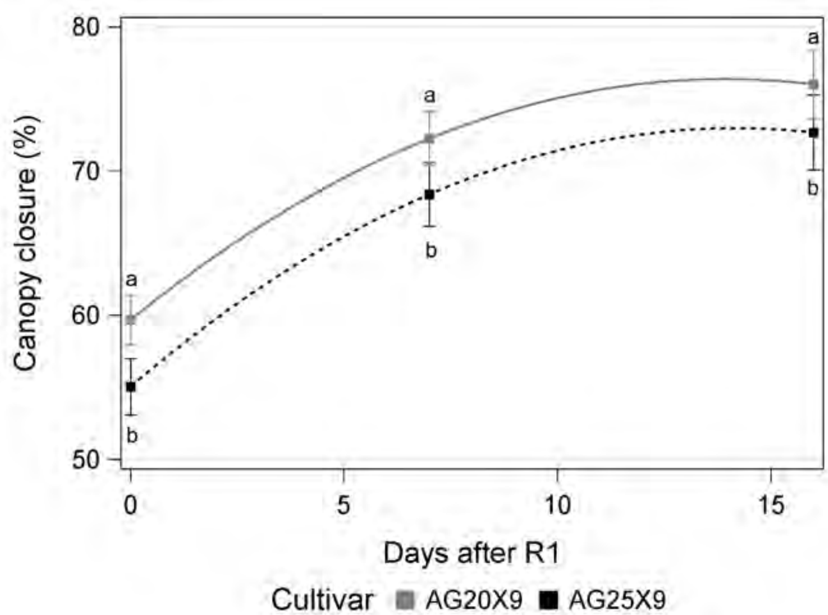
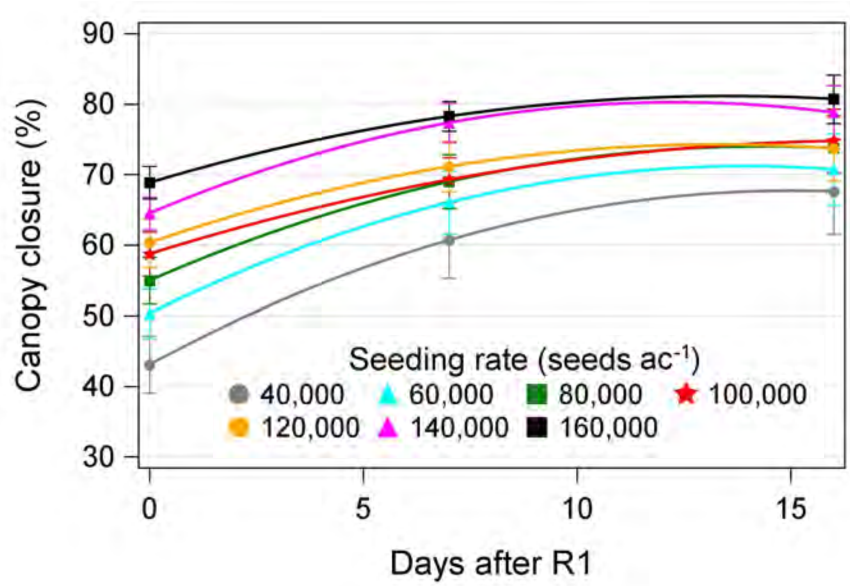


Figure 5. Percent canopy closure, between R1 (first flower) and R1 + 16 days, as affected by seven seeding rates across 2019 and 2020. Error bars show the standard error of the mean.



Main effects of seeding method (P<0.001), cultivar (P=0.042) and seeding rate (P<0.001) had a variable effect on the progression of canopy closure during the 16-day period after R1 growth stage. Regardless of seeding rate and cultivar, the precision seeding method resulted in greater canopy closure compared to random seeding at R1 and 7 days after R1; however, the difference was not significant at 16 days after R1 (Figure 3). A greater percent of canopy closure, regardless of seeding rate and seeding method, was observed for the early maturity cultivar compared to the later maturity for every measurement after R1 (Figure 4). Seeding rate, regardless of cultivar and seeding method, also had a significant effect on percent canopy closure with greater rates resulting in increased closure in all measurement days after R1 (Figure 5).

Plant architecture

In this study, significant differences were observed in partitioned seed yield (branch and stems) across the range of seeding rates (Figure 6). As seeding rate increased, the percent of branch and stem yield, out of the total yield, varied for the two greatest seeding rates (110,000 and 140,000 seeds ac^{-1}) but no differences were observed for the low rates (50,000 and 80,000 seeds ac^{-1}). These results suggest that in low seeding rates, total yield is produced by pods on branches and stems in similar proportions; however, in greater seeding rates, most of total seed yield (*c.a*. 80%) results from pods on main stems.

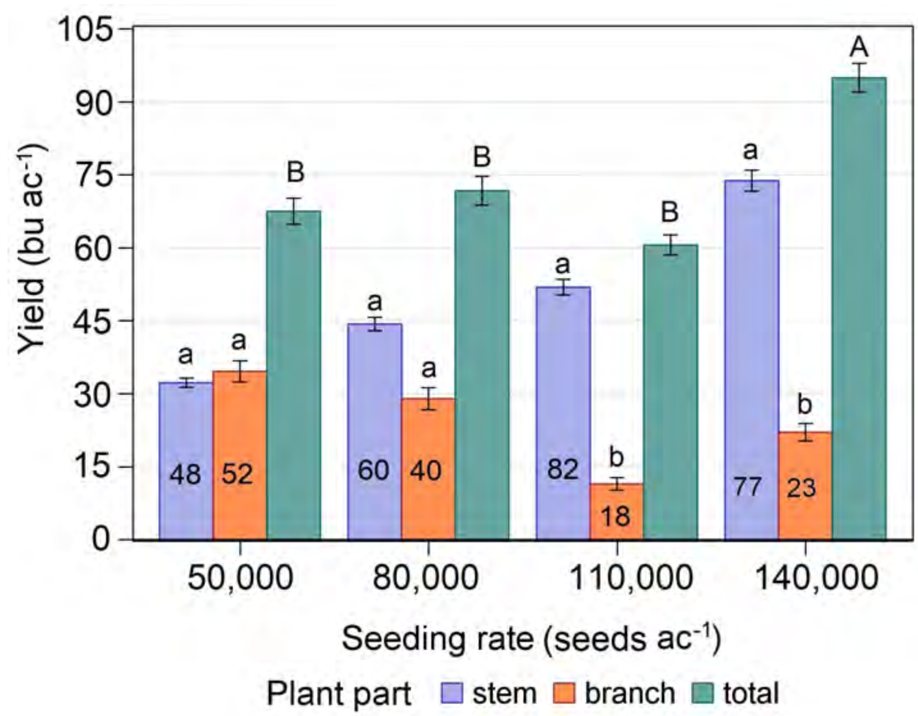


Figure 6. Total and partitioned (branch and stems) soybean seed yield for four seeding rates across 2019 and 2020. Within each bar, the percentages of stem and branch yield, out of total yield, are numerically reported. Stem and branch yields within each seeding rate with the same (lower case) letters are not significantly different at alpha=0.05. Total yields with the same (upper case) letters are not significantly different among seeding rates at alpha=0.05.

DISCUSSION

Increasing seed cost can affect overall farm profitability and farmers should optimize the seeding rate that ensures maximum return of investment. The results of the first study suggest that soybean response to seeding rate can vary due to other management practices and thus, general recommendations ignoring cultivars and seeding methods may be misleading. The 7% yield difference which was observed between the two examined cultivars at the highest seeding rate, and the 18% yield difference, which was observed between the two examined seeding methods at the lowest seeding rate, can greatly affect final yield and may result in variable farm profitability.

Early canopy closure can increase capture of solar radiation during reproductive growth stages and theoretically, enhance seed yield. At the lowest seeding rate, the precision method resulted in more uniform in-row plant-to-plant spacing as well

as in increased canopy closure when compared to random seeding, which could explain the observed yield difference. Additionally, the yield difference between the greatest and lowest seeding rate reached 12% for precision and 29% for random seeding methods. Thus, it appears that precision planting can mitigate a potentially large yield loss at sub-optimal seeding rates (compared to University recommended rates). This could be associated with the results from the second study, which was hand planted and therefore seeding rate was precise and plant-to-plant spacing was uniform. In this study, there were no yield differences among the three lower seeding rates and the increased branch-derived yield was similar to the stem-derived yield. These results are in agreement with previous studies (Carpenter & Board, 1997; Epler & Staggenborg, 2008; Suhre et al., 2014).

CONCLUSIONS

These studies reveal the complexity of seeding rate optimization for yield since cultivar and seeding method should also be considered. An even more difficult task is seeding rate optimization for profit where variable soybean price, region-specific seed cost, and cost of seeding method are important variables that a farmer must consider. Therefore, we highlight the need for farm-specific economic analysis for different management-related costs and farm gate soybean price scenarios.

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