Soybean Seeding Rate and Nutrient Interactions on Growth and Yield in Michigan

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ABSTRACT

Soybean (*Glycine max* L. Merr.) prices are forecast to remain stagnant placing greater emphasis on production costs for growers across Michigan. Seeding rates and fertility inputs are two factors producers can manage to influence economic return. Field research was conducted in Richville and Lansing, MI in 2017 to evaluate biomass production and yield in response to nutrient inputs and help determine economically optimal seeding rates. The study was designed as a randomized complete block split plot arrangement with four seeding rates as main plots and four fertility treatments as subplots. Plants were sampled at three different growth stages to determine biomass accumulation and partitioning. Soybeans seeded at lower plant populations produced more biomass per plant which was inversely related to seeding rate. MESZ significantly increased biomass per acre at all sample timings, but had a greater influence at lower seeding rates. Total dry matter production per acre reached a plateau at 130,000 seeds A^{-1}. Seeding rate had no significant effect on total dry matter or biomass partitioning at R5 indicating that seeding rates between 50,000 - 170,000 seeds A^{-1} produced similar total biomass.

INTRODUCTION

Michigan soybean production ranks 12th in the United States (U.S.) and produced an annual value of approximately $983 million in 2016 (USDA-NASS, 2017). Although soybean yields in Michigan are similar to those of the U.S. average and have increased 35% over the past 20 years (USDA-NASS, 2017), producers continue to look for ways to decrease production costs without sacrificing revenue. In modern soybean varieties, increased seeding rates can be used to increase yield potential but this can negatively influence yield by creating more inter-plant competition and the increased seed cost may outweigh yield benefits (Holliday, 1960; Norsworthy and Oliver, 2001; Suhre et al., 2014). Within the five yield-limiting factors identified by Ciampitti and Vyn (2014), planting density and nutrient availability are two that producers can regularly influence to manage environmental variability in Michigan.

Optimal seeding rates for soybean producers in the U.S. vary and are influenced by multiple agronomic practices and environmental conditions (Isidro-Sánchez et al., 2017), including maturity group (MG) (Chen and Wiatrak, 2011a), weed management (Norsworthy and Oliver, 2001), and row spacing (Devlin et al., 1995). However, seeding rates maximizing yield often do not result in economically optimal seeding rates, due in part to the national average seed cost nearly doubling over the past 10 years (USDA-ERS, 2017). De Bruin and Pedersen (2008) suggested greater emphasis be placed on economic return rather than optimal yields. They reported 95% maximum yield was obtained by seeding 105,000 seeds A^{-1}, a 44% decrease from the seeding rate used to obtain maximum yield. Chen and Wiatrak (2011) reported a rate of

103,300 seeds A^{-1} achieved maximum yield while a rate of 93,300 seeds A^{-1} achieved maximum economic return in a MG V soybean. Studies suggest producers in Michigan have the potential to decrease seeding rates while maintaining maximum economic return.

Soil fertility management can be used as a tool to reduce risks associated with environmental variability. The use of a subsurface band, or 2x2, has increased early-season growth and allowed producers to plant into cool, wet soils (Niehues et al., 2004). Michigan State University recommends using a 2x2 placement in corn of up to 40, 100, and 100 pounds A^{-1} of N, P_2O_5, and K_2O, respectively (Warncke et al., 2009). Soybeans however have the ability to form symbiotic relationships with soil microorganisms and supply nitrogen requirements through N_2 fixation (Russelle, 2008). Although nitrogen applications are not always feasible and can reduce nodulation (Ham et al., 1975), Osborne and Riedell (2006) reported an increase in early-season biomass with the application of 14 lbs N A^{-1} in a 2x2, resulting in a yield increase between 5.3 and 7.2%. Ham et al. (1975) also saw a yield increase with N applied in a 2x2, suggesting the soybeans got a better "start" because of increased early-season biomass.

Previous studies have documented biomass accumulation and partitioning in modern soybean varieties (Bender et al., 2015) across multiple yield levels (Gaspar et al., 2017). For example, Bender et al. (2015) reported a final biomass of 8500 lbs A^{-1} yielding 51.7 bu A^{-1}, which was partitioned among leaves, stems, pods, and grain by 16%, 33%, 14%, and 37%, respectively. Gaspar et al. (2017), however, was able to produce a slightly higher yield of 53.6 bu A^{-1} with less total biomass (6600 lbs A^{-1}) indicating biomass was more efficiently partitioned to grain tissues (harvest index of 42.8). In addition, seeding rates between 32,400 and 157,800 plants A^{-1} in determinate cultivars produced similar quantities of biomass per acre by producing more biomass per plant at the lower seeding rates (Board, 2000). The objectives of this study were to 1) determine economically optimal seeding rates in Michigan, 2) evaluate biomass accumulation in response to nutrient applications, and 3) assess biomass partitioning across varying seeding rates.

MATERIALS AND METHODS

Field research was initiated in Michigan to evaluate the interaction between seeding rates and nutrient inputs and the effect on biomass accumulation and partitioning. Trials were planted on 28 April 2017 in Richville, MI on a Tappan-Londo (fine-loamy, mixed, active, calcareous, mesic Typic Epiaquolls) loam soil and on 10 May 2017 in Lansing, MI on a Capac (fine-loamy, mixed, active, mesic Aquic Glossudalf) loam. Both sites were previously cropped to corn. Preplant soil properties in Richville included 8.2 pH, 2.6% Organic Matter (OM), 23 ppm P, 155 ppm K, 7 ppm, S, and 6.0 ppm Zn. Lansing preplant soil properties consisted of 6.6 pH, 2.1% OM, 30 ppm P, 134 ppm K, 8 ppm S, and 2.3 ppm Zn.

The experiments were designed as a randomized complete block split-plot arrangement with four replications. Main plot factor was four seeding rates while subplots consisted of four fertilizer treatments. Trial locations were both chisel plowed in the fall and field cultivated twice the day of planting. The soybean variety used in both trials was AG2535 (Monsanto Co., St. Louis, MO) in 30 inch rows to achieve seeding rates of 55,000, 90,000, 130,000, and 170,000 seeds A^{-1}. A seeding rate of 50,000 seeds A^{-1} was desired as the lowest seeding rate, therefore plots planted at 55,000 seeds A^{-1} were thinned to 50,000 plants A^{-1} at the V1 growth stage (Hicks et al., 2013) according to the description of Fehr et al. (1971). Four fertilizer treatments included a non-fertilized control, MicroEssentials SZ ([MESZ (Mosiac Co., Plymouth, MN]) applied 2-in below and 2-in to the side of the seed at a rate of 150 pounds MESZ A^{-1}, K broadcast and incorporated prior to planting at 50 lbs K_2O A^{-1}, and a combination of K pre-plant incorporated at 50 lbs K_2O A^{-1} and MESZ applied 2-in below and 2-in to the side of the seed at a rate of 150 pounds MESZ A^{-1}.

Aboveground plant biomass was sampled at V4, R2, R5, and R8 when at least 50% of the crop achieved the respective growth stage (Fehr et al., 1971). Sampling areas were randomly selected and 10 consecutive plants were harvested and partitioned into leaves, stems/petioles, flowers/pods, and grain (Bender et al., 2015). Total plant weight was the sum of all partitioned weights. Immediately prior to the beginning of leaf senescence, 0.5-in bird netting was wrapped around 10 consecutive plants to collect fallen leaves and petioles for the final sampling period. To determine final dry weight for each sample, plants were dried at 65˚C. Biomass data collected at R5 were presented in three plant parameters (leaves, stems and petioles, and pods and grain) due to the difficulty of removing the grain from the pods. Final grain yield will be taken and adjusted to 13.0% moisture. Economic analysis will be performed using cost estimates of $37.00 and $12.08 A^{-1} for MESZ and K_2O, respectively. An additional $8.00 A^{-1} is estimated for the dry fertilizer application cost and an additional $82.50 per unit (140,000 seeds) of AG2535. Gross profit estimates will be calculated using a cash grain price of $8.88 bu^{-1}, and the net profit estimates will be calculated by subtracting treatment costs (US$ A^{-1}) from the gross profit estimates.

Statistical analyses were performed using PROC GLIMMIX (SAS Institute, 2009) at $\alpha = 0.10$ to determine seeding rate and fertility inputs on biomass accumulation. Individual R5 plant weights were presented separately for each site due to a significant effect of location (Table 2). All biomass values were reported on a dry weight basis (0% moisture).

PRELIMINARY RESULTS AND DISCUSSION

Total rainfall between 1 April and 31 August 2017 was 0.9 inches above and 0.9 inches below normal for Richville and Lansing, respectively. Between April and June, Richville and Lansing received greater than normal amounts of precipitation (3.4 inches and 1.0 inches above the 30-year mean, respectively), but below normal amounts in July and August during soybean reproductive phases. Average daily temperatures in April were considerably warmer than the long-term average in Richville (+4.5˚F), but much lower in Lansing (-4.6˚F), and ±1.5˚F for May, June, and July at both locations.

Biomass accumulation was significantly affected by seeding rate at V4 ($P < .0001$). As seeding rate increased from 50,000 to 170,000 seeds A^{-1}, biomass decreased from 1.10 g to 0.65 g $plant^{-1}$, respectively, in the unfertilized control plots (Table 1). Fertilizer management also had a significant effect on biomass accumulation per plant where MESZ increased biomass per plant by 118%, 108%, 108%, and 72% at 50,000, 90,000, 130,000, and 170,000 seeds A^{-1}, respectively. There were no significant differences in biomass accumulation with K_2O. A significant interaction occurred between seeding rate and fertility management at V4 ($P < .0001$). In the control plots, seeding rates of 130,000 and 170,000 seeds A^{-1} produced similar amounts of dry matter (Table 1). MESZ, however, increased total biomass per plant at 130,000 seeds A^{-1} resulting in significant differences in per plant biomass accumulation between the two seeding rates. In addition, biomass accumulation per plant increased more at lower seeding rates indicating lower plant populations responded better to MESZ applications.

Seeding rate had a significant effect on biomass accumulation per plant at R5. As seeding rate increased, total dry matter per plant decreased (Table 2). At 130,000 seeds A^{-1}, a plateau was reached where biomass accumulation per plant remained similar despite further increases in seeding rate regardless of fertility inputs with the exception of MESZ in Lansing. Total dry matter increased by 36% at 130,000 seeds A^{-1} in Lansing with the addition of MESZ but only increased biomass by 5% in Richville. Therefore, there was no biomass accumulation plateau in Lansing at 130,000 seeds A^{-1} with MESZ only.

Combined across sites, seeding rate had a significant effect on biomass accumulation per acre at V4 and R2 but not R5 (Table 3). As seeding rate increased at V4, total dry matter per acre increased. A plateau was reached at 130,000 seeds A^{-1}, however, and no significant increases in biomass production were observed with further increases in seeding rate. This is a relative indicator that interplant competition may not occur until soybeans are seeded above 130,000 seeds A^{-1}. By the time the soybeans reached maximum biomass accumulation at R5, there were no differences in total dry matter produced per acre across seeding rates suggesting soybeans are able to compensate for seeding rate differences by producing more biomass per plant. Fertilizer management also had a significant effect on biomass accumulation per acre ($P < .0001$) but no fertility by seeding rate interaction occurred at any plant sampling periods. As with total dry matter on a per plant basis, K_2O did not affect total dry matter accumulation. MESZ increased total dry matter by 105% at V4, but increases slowly diminished throughout the season and resulted in only a 44% increase in biomass at R2 and a 19% increase at R5 (Table 3). Nevertheless, MESZ increased early-season biomass and may have given soybeans a better start-right capacity.

As the soybeans developed from early vegetative stages into reproductive stages, biomass production shifted from primarily accumulating biomass in leaves to primarily accumulating biomass in stems and petioles. At V4, biomass partitioned to leaves ranged between 66 and 70%, depending on seeding rate, but resulted in only 35-36% at the R5 sampling period (Table 4). Seeding rates between 90,000 and 170,000 seeds A^{-1} partitioned similar amounts of biomass at all sampling periods when averaged across sites. The 50,000 seeds A^{-1} rate, however, partitioned slightly more biomass into leaves at V4 and R2, possibly trying to compensate for seeding rate differences and achieve row closure. Fertilizer input effected biomass partitioning at V4 and R2, as the MESZ partitioned more biomass in the stems and petioles than the unfertilized control and K_2O plots. At R5, however, seeding rate or fertility input had no effect on biomass partitioning.

Yield and economic return will be analyzed and presented by poster at the North Central Extension-Industry Soil Fertility Conference.

PROJECT CONTINUATION

A second year of research will be conducted in 2018. The authors would like to thank Andrew Chomas for his guidance and encouragement in field research activities, as well as the Michigan Soybean Promotion Committee for their support and funding throughout this project.

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Table 1. Total biomass accumulation per plant across sites, 2017. Parameters were measured at V4 and reported on a dry weight basis (0%) moisture.

Fertility	Seeding Rate				$P_r > F$
	50,000	90,000	130,000	170,000	
	------------g plant^{-1}† ------------				
None	1.10 aA‡	0.87 aB	0.76 aBC	0.65 aC	0.001
K_2O	1.12 aA	0.86 aB	0.76 aBC	0.67 aC	0.001
MESZ	2.40 bA	1.81 bB	1.58 bC	1.12 bD	<.0001
K_2O + MESZ	2.42 bA	1.82 bB	1.48 bC	1.16 bD	<.0001
$P_r > F$	<.0001	<.0001	<.0001	<.0001	

† 1 gram (g) = 0.035274 ounces (oz).
‡ Capital letters are specific to each row (fertility treatment) and lowercase letters are specific to each column (seeding rate). Values followed by the same lowercase or uppercase letter are not significantly different at α = 0.10.

Table 2. Total biomass accumulation per plant at Richville and Lansing, 2017. Parameters were measured at R5 and reported on a dry weight basis (0%) moisture.

Fertility	Lansing					Richville				
	Seeding Rate				$P_r > F$	Seeding Rate				$P_r > F$
	50,000	90,000	130,000	170,000		50,000	90,000	130,000	170,000	
	----------g plant^{-1}†----------					----------g plant^{-1}----------				
None	40.9 aA‡	22.9 aB	15.4 aC	13.2 aC	<.0001	44.8 aA	22.1 aB	18.2 aBC	13.5 aC	<.0001
K_2O	40.1 aA	23.0 aB	14.8 aC	15.1 aC	<.0001	38.0 bA	25.2 abB	18.8 aC	14.0 aC	<.0001
MESZ	52.2 bA	27.5 aB	20.9 bC	13.9 aD	<.0001	39.6 bA	28.0 bB	19.1 aC	15.8 aC	<.0001
K_2O + MESZ	56.4 bA	24.4 aB	18.7 abC	14.6 aC	<.0001	41.7 abA	29.3 bB	21.7 aC	17.0 aC	<.0001
$P_r > F$	<.0001	ns§	ns	ns		ns	ns	ns	ns	

† 1 gram (g) = 0.035274 ounces (oz).
‡ Capital letters within each row and lowercase letters within each column are specific to location. Values followed by the same lowercase or uppercase letter are not significantly different at α = 0.10.
§ ns, not significant.

Table 3. Total biomass accumulation per acre across sites, 2017. All values are reported at 0% moisture.

Treatment	Total Biomass Accumulation		
	V4†	R2	R5
		lbs A^{-1}	
Seeding Rate			
50K	197 a‡	1468 a	4804 a
90K	264 b	1626 ab	4967 a
130K	317 c	1841 c	5148 a
170K	306 c	1786 bc	4949 a
$P_r > F$	<.0001	0.0037	ns§
Fertility			
None	177 A	1359 A	4464 A
K_2O	181 A	1418 A	4650 A
MESZ	363 B	1951 B	5300 B
K_2O + MESZ	364 B	1993 B	5453 B
$P_r > F$	<.0001	<.0001	<.0001

† Growth stages based on the description of Fehr et al. (1971).

‡ Capital letters within each row and lowercase letters within each column are specific to location. Values followed by the same lowercase or uppercase letter are not significantly different at α = 0.10.

§ ns, not significant.

Table 4. Total dry weight partitioning separated by seeding rate and fertility input averaged across sites, 2017. All values are reported as a percentage.

Treatment	Total Dry Matter Accumulation†							
	V4		R2			R5		
	Leaves	Stems/ Petioles	Leaves	Stems/ Petioles	Flowers/ Pods	Leaves	Stems/ Petioles	Pods/ Grain
	%		%			%		
Seeding Rate								
50K	70	30	59	40	1	36	52	12
90K	66	34	55	43	2	36	50	14
130K	67	33	53	45	2	35	50	15
170K	66	34	53	46	2	35	50	15
Fertility								
None	70	30	56	42	2	36	51	13
K_2O	70	30	57	41	2	36	50	14
MESZ	65	35	53	45	2	35	50	15
K_2O + MESZ	66	34	53	45	2	35	50	15

† Values were derived as a percentage of total dry weight per acre.