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GROWTH AND YIELD RESPONSES OF SOYBEAN TO ROW SPACING AND SEEDING RATE

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Abstract

Some growers in Bihor County plant soybean with a row crop planter in 0.45 m rows, but an economic analysis concluded that drilled soybean in rows <0.25 m was optimum in the county. We planted two varieties in 0.125, 025, and 0.50 m rows at 321,000; 371,000; 420,000; and 469,000 seeds ha^{-1} in Biharia in 2008 and 2009 to evaluate how soybean compensates to wide rows or low seeding rates in the Bihor county. Soybean compensated more at lower seeding rates than at wider rows, but field-scale studies are being conducted to evaluate the economics of both practices.

Key words*:agricultural holdings,farms, agricultural products*

INTRODUCTION

Some growers plant soybean in 0.38 m instead of 0.76 m rows because of consistent yield increases at latitudes north of 43 N (Lee, 2006), and increased prevalence of split-row planters allowing soybean planting in 0.38 m rows and corn (Zea mays L.) planting in 0.76 m rows with the same planter (De Bruin and Pedersen, 2008b). Lambert and Lowenberg- DeBoer (2003), however, concluded that planting soybean in 0.19 m rows with a grain drill was more economical in an annual corn-soybean rotation in the North-Central United States, based on a summary of studies showing a 4.8% yield advantage for drilled (<0.25 m rows) compared with 0.38 m rows. Furthermore, Kratochvil et al. (2004) reported that drilled soybean in 0.19 vs. 0.38 m rows yielded the same or more in 47 of 48 cultivar/row spacing comparisons in a 3-yr study for full-season and double-cropped soybean in Maryland. Consequently, it is not clear if growers should plant soybean in 0.38 m rows with a row crop planter instead of 0.19 m rows with a grain drill in northern latitudes, especially if growers still plant wheat with grain drills.

Results from the more recent studies in northern latitudes indicate no consistent yield advantage for drilled soybean in 0.19 m rows compared to 0.38 m rows.

Soybean management practices (including variety-growth habit, full-season vs. double-cropped soybean, row spacing, seeding rates, etc.) vary greatly across different regions of the United States and currently no published research exists on row spacing by seeding rate interactions in the Northeast United States. Cox et al. (2010) recently reported that drilled soybean in 0.19 m rows compensated for increased space at lower seeding rates (358,000 seeds ha^{-1}) by increasing branch, biomass, pods and seeds plant-1, which resulted in similar yield across seeding rates in New York. In contrast, soybeans did not compensate for increased space as thinning rates increased (10, 25, and 50% plant removal) at the sixth node stage (Cox et al., 2010). The objective of this study was to evaluate growth and yield components of soybean at three row spacings and four seeding rates to determine how soybeans compensate under different row spacing and seeding rate combinations.

MATERIAL AND METHODS

Field experiments were conducted in 2008 and 2009 on a preluvo soil soil at Bizoofruct, Biharia . The experimental site has been in a corn-soybean rotation since 2000. Soil tests in both years indicated a pH of 6.8 with high concentrations of P and K.

The experimental site was chisel plowed the day before planting and disked-harrowed the day of planting in both years. The experimental design was a randomized complete block in a split-split-plot arrangement, replicated three times, with two varieties as main plots, three row spacings (0.125, 0.25, and 0.50 m) as subplots, and four seeding rates as sub-subplots. Main plots measured 35 by 10.7 m, subplots measured 35 by either 4.6 m (0.125 m row spacing) or 3.1 m (0.25 and 0.50 m row spacing), and sub-subplots measured 8.75 m by 4.6 or 3.1 m oriented in a North-South direction. Pioneer brand, "B63", a late Maturity Group I variety, and another Pioneer brand, "M10", an early Maturity Group II variety, were inoculated on the day of planting with Bradyrhizobium japonicum. Both varieties have medium canopy widths (according to company ratings). Both varieties were planted on 13 May 2008 and 11 May 2009 with a 4.6-m wide grain drill (Model 5400, Case IH, Racine, WI) in 0.125 m rows or a 3.3 m wide 7-row White Split-Row Planter (Coldwater, OH) with functioning inter-units for 0.25 m rows or nonfunctioning inter-units for 0.50 m rows. Seeding rates approximated 321,000; 370,000; 420,000; and 469,000 seeds ha-1 (based on calibration of both varieties at different drill settings or calibration of the White Air Seeder at both row spacings).

All plants in a 0.57 m^2 area in the 0.125 m and 0.25 m rows and a 0.50 m^2 area in the 0.50 m row were hand-harvested and counted on 18 August 2008 and 20 August 2009, the beginning of seed development (R5 stage), to determine plant density, leaf area $plant^{-1}$ (using a LI-3100 leaf area meter, LI-COR, Lincoln, NE) and biomass plant^{-1} (after drying the plants in a forced air drier at 60°C for 48 h). Then was calculated LAI and aboveground biomass m^{-2}, based on the respective sampling areas.

From these data were calculated seeds plant^{-1}, seeds pod^{-1}, seeds m^{-2}, and seed mass (mg). Final plant densities were determined from the average of plant counts at the R5 and harvest sampling dates.

Variety, row spacing, and seeding rate were considered fixed, and year and replication were considered random effects in the ANOVA using PROC MIXED . The Bartlett test (P = 0.01) indicated that all variances were homogeneous across years. The Shapiro-Wilk statistic in the PROC CAPABILITY: NORMAL TEST option of SAS indicated normality for all data. Orthogonal contrasts were used to test the responses of the measured variables to the three row spacings and four seeding rates within the ANOVA by partitioning the sums of squares into linear and quadratic components (the quadratic was also the lack of fit for row spacings because there were only three spacings). The contrast coefficients for seeding rate were -3 - 1 + 1 - 3 for the linear and +1 - 1 - 1 + 1 for the quadratic contrasts. The contrast coefficients for row spacing were -1 0 + 1 for the linear and +1 - 2 + 1 for the quadratic contrasts. Significance was determined at P = 0.05. Varieties showed no three-way and only two two-way interactions with row spacing so results will be averaged over varieties with mention in the text where variety by row spacing interactions were observed.

RESULTS AND DISCUSSIONS

Overall growing conditions were similar in 2008 and 2009, despite monthly differences in total precipitation and average temperature (Table 1). Precipitation from May through August totaled 347 mm in 2008 and 372 mm in 2009, close to normal (360 mm). Temperatures from May through August averaged 18.7°C in 2008 and 18.5°C in 2009, slightly cooler than normal (19.0°C).

Table 1.

Monthly precipitation and average monthly temperatures at Biharia, Bihor, during the 2008 and 2009 growing seasons.

	Precipitation			Avg. Temperature		
Month	**2008**	**2009**	**30-yr avg.**	**2008**	**2009**	**30-yr a**
					°C	
		mm				
May	35	96	80	12.2	14.5	14.2
June	97	121	104	20.9	18.1	19.3
July	138	62	84	22.1	19.8	21.8
August	77	93	92	19.6	21.5	20.9
September	46	66	107	16.1	18.4	16.7

Table 2.
Early stand (mid-June), final stand (averaged at the beginning of seed development and at harvest), plant height and branches plant^{-1} at harvest of soybean in three row spac-ings at four seeding rates, averaged over two varieties and the 2008 and 2009 growing seasons at Aurora, NY.

Seeding rates	**Row spacing** 0.125 m	0.25 m	0.50 m	Avg.
Early stand, plants m^{-2}				
321,000 seeds ha^{-1}	24.7	22.5	20.7	22.6
371,000 seeds ha^{-1}	26.0	21.7	24.5	24.1
420,000 seeds ha^{-1}	31.6	29.6	28.9	30.0
469,000 seeds ha^{-1}	30.2	33.0	31.3	31.5
Avg.	28.1	26.7	26.4	
Final stand, plants m^{-2}				
321,000 seeds ha^{-1}	24.8	21.1	23.6	23.2
371,000 seeds ha^{-1}	27.0	25.1	23.5	25.2
420,000 seeds ha^{-1}	27.6	28.1	29.6	28.4
469,000 seeds ha^{-1}	31.2	28.5	26.4	28.7
Avg.	27.7	25.7	25.8	
Plant height, cm				
321,000 seeds ha^{-1}	89	87	85	87
371,000 seeds ha^{-1}	90	89	85	88
420,000 seeds ha^{-1}	91	90	87	89
469,000 seeds ha^{-1}	90	89	87	89
Avg.	90	89	86	
Branches, no. plant^{-1}				
321,000 seeds ha^{-1}	2.4	2.9	2.2	2.5
371,000 seeds ha^{-1}	2.5	2.8	2.2	2.5
420,000 seeds ha^{-1}	2.1	2.2	1.9	2.1
469,000 seeds ha^{-1}	2.1	2.0	2.1	2.1
Avg.	2.3	2.5	2.1	
Significance (P values)	Early stand	Final stand	Plant height	Branches
Row spacing	0.07	0.08	0.02	0.08
Linear	0.04	0.06	0.007	0.21
Quadratic	0.05	0.20	0.25	0.06
Seeding rate	<0.0001	<0.0001	0.17	0.01
Linear	<0.01	<0.0001	0.07	0.004
Quadratic	0.54	0. 52	0.27	0.90
Row spacing x Seeding rate	0.11	0.16	0.99	0.53

Early plant densities at the V3 stage did not differ among row spacings (Table 2), despite the potential for higher emergence rates with a row crop planter (Bertram and Pedersen, 2004; Epler and Staggenborg, 2008).

Final plant densities, as expected, had a linear response to seeding rate with no row spacing by seeding rate interaction (Table 2).

Plant height had a linear response to row spacing but no response to seeding rate and no row spacing by seeding rate interaction (Table2). Differences in plant height among row spacings, however, were small (86-90 cm). Branches plant^{-1} did not respond to row spacing, but had a linear response to seeding rate with no row spacing by seeding rate interaction (Table 2).

Table 3.
Leaf area and biomass plant^{-1}, leaf area index (LAI), and aboveground biomass accumulation at seed initiation (R5) stage of soybean in three row spacings at four seeding rates, averaged over two varieties and the 2008 and 2009 growing seasons at Aurora, NY.

	Row spacing			
Seeding rates	**0.125 m**	**0.25 m**	**0.50 m**	**Avg.**
Leaf area, cm^2 plant^{-1}				
321,000 seeds ha^{-1}	1360	1848	1610	1606
371,000 seeds ha^{-1}	1042	1444	1510	1332
420,000 seeds ha^{-1}	1414	1644	1435	1498
469,000 seeds ha^{-1}	1325	1299	1371	1332
Avg.	1285	1559	1481	
Biomass plant^{-1}, g plant^{-1}				
321,000 seeds ha^{-1}	22.6	30.8	25.7	26.3
371,000 seeds ha^{-1}	17.4	21.3	23.2	20.6
420,000 seeds ha^{-1}	21.6	25.7	21.2	22.8
469,000 seeds ha^{-1}	20.0	19.1	20.5	19.9
Avg.	20.4	24.2	22.7	
LAI, m^2 m^{-2}				
321,000 seeds ha^{-1}	3.65	3.45	3.21	3.44
371,000 seeds ha^{-1}	3.45	3.54	3.21	3.40
420,000 seeds ha^{-1}	3.72	3.43	3.24	3.46
469,000 seeds ha^{-1}	3.71	3.46	2.98	3.38
Avg.	3.64	3.47	3.16	
Biomass, g m^{-2}				
321,000 seeds ha^{-1}	595	580	534	570
371,000 seeds ha^{-1}	600	534	484	539
420,000 seeds ha^{-1}	595	580	506	561
469,000 seeds ha^{-1}	601	520	462	528
Avg.	598	554	497	
Significance (P values)				
Row spacing	0.03	0.05	0.02	0.01
Linear	0.04	0.14	0.006	0.004
Quadratic	0.05	0.05	0.62	0.80
Seeding rate	0.10	0.002	0.98	0.56
Linear	0.11	0.003	0.88	0.32
Quadratic	0.56	0.28	0.87	0.95
Row spacing x Seeding rate	0.56	0.31	0.96	0.95

Leaf area plant^{-1} at the R5 stage had linear and quadratic responses to row spacing but no response to seeding rate and no row spacing by seeding rate interaction (Table 3). Biomass plant^{-1} had a quadratic response to row spacing and a linear response to seeding rate with no interaction between row spacing and seeding rate (Table 3).

Leaf area index (LAI) and biomass accumulation at the R5 stage had linear responses to row spacing but no responses to seeding rate and no row spacing by seeding rate interaction (Table 3). The LAI and biomass accumulation data indicate that wider row spacing, especially 0.50 m rows, may have more of a negative impact on yield than lower seeding rates, especially in 0.125 m rows, in this environment.

Table 4

Pods plant-1, pod density (pods m-2), seeds pod-1, and seeds plant-1 of soybean in three row spacings and four seeding rates, averaged over two varieties and the 2008 and 2009 growing seasons at Aurora, NY.

Seeding rates	Row spacing 0.125 m	0.25m	0.50 m	Avg.
Pod plants^{-1}				
321,000 seeds ha^{-1}	40.2	40.8	34.5	38.5
371,000 seeds ha^{-1}	37.4	38.6	31.8	35.9
420,000 seeds ha^{-1}	31.3	29.4	30.2	30.3
469,000 seeds ha^{-1}	28.7	30.9	31.1	30.2
Avg.	34.4	35.0	31.9	
Pods m^{-2}				
321,000 seeds ha^{-1}	1020	944	840	934
371,000 seeds ha^{-1}	1056	953	820	943
420,000 seeds ha^{-1}	1003	948	945	965
469,000 seeds ha^{-1}	970	898	895	921
Avg.	1012	935	875	
Seeds pod^{-1}				
321,000 seeds ha^{-1}	2.33	2.45	2.36	2.38
371,000 seeds ha^{-1}	2.27	2.30	2.46	2.34
420,000 seeds ha^{-1}	2.33	2.44	2.32	2.36
469,000 seeds ha^{-1}	2.28	2.31	2.34	2.31
Avg.	2.30	2.37	2.37	
Seeds plant^{-1}				
321,000 seeds ha^{-1}	94	100	82	92
371,000 seeds ha^{-1}	85	89	78	84
420,000 seeds ha^{-1}	73	72	70	72
469,000 seeds ha^{-1}	66	71	73	70
Avg.	80	83	76	
Significance (P values)	Pods plant^{-1}	Pods m^{-2}	Seeds pod^{-1}	Seeds plan
Row spacing	0.21	<0.001	0.04	0.12
Linear	0.79	<0.001	0.05	0.82
Quadratic	0.09	0.76	0.07	0.05
Seeding rate	0.0001	0.65	0.67	<0.001
Linear	<0.0001	0.87	0.27	<0.001
Quadratic	0.90	0.30	0.77	0.99
Row spacing x Seeding rate	0.07	0.39	0.03	0.11

Pods plant^{-1} had no response to row spacing but a linear response to seeding rate with no row spacing by seeding rate interaction (Table 4).

Seeds pod^{-1} responded to row spacing and not to seeding rates in this study but a row spacing by seeding rate interaction occurred (Table 4).

Seeds plant^{-1} had a linear response to seeding rate but did not respond to row spacing or have a row spacing by seeding rate interaction (Table 4).

CONCLUSIONS

Drilled soybean in 0.125 m rows had a higher yield potential when compared with soybean planted with a row crop planter in wider rows because greater crop growth by the R5 stage (greater LAI and biomass accumulation) resulted in greater pod and seed density at harvest and subsequent yield. Despite similar LAI and biomass accumulation at the R5 stage and similar pod and seed density at harvest, soybean yield had a quadratic response to seeding rate with maximum yield of all three row spacings at 420,000 seeds ha^{-1}. Apparently, soybean compensation in both vegetative and reproductive growth to increased space within the row was not adequate to maintain soybean yield at a seeding rate of 321,000 seeds ha^{-1}. The results indicate that soybean has the greatest yield potential in 0.125 m rows at seeding rates of420,000 seeds ha^{-1} in this study. In addition to crop growth and yield potential, however, equipment costs (De Bruin and Pedersen, 2008a), prevalence of Sclerotinia stem rot (Sclerotinia sclerotiorum) or white mold , wheel-track damage from postemergence pesticide applications , and weed competitiveness at different row spacing also influence optimum soybean row spacing in a particular environment. Furthermore, optimum economic seeding rates are often less than seeding rates that result in maximum yield because of the high costs of soybean seed (Lee et al., 2008; De Bruin and Pedersen, 2008b).

We are currently conducting field-scale studies on three farmers' fields to determine if the greater yield potential of drilled soybean in 0.125 m rows at 420,000 seeds ha^{-1} translates into the economic optimum soybean row spacing and seeding rates in the North West of Romania.

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