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Influence of Integrated Agronomic and Weed Management Practices on Soybean Canopy Development and Yield[1]

Take Home Message

- All practices investigated herein (planting time, row spacing, tillage practice, and PRE-emergence herbicide application) influenced the time of soybean canopy closure but only planting time and tillage impacted yield.
- Planting soybeans earlier and reducing the row spacing expedited the time to canopy closure.
- The potential delay in canopy development and yield loss if soybeans are allowed to compete with weeds early in the season likely outweigh the slight delay in canopy development by an effective PRE-emergence herbicide.

Introduction

Restoration of diverse and integrated weed management (IWM) strategies based on the practices of crop rotation, competitive crop cultivars, cover crops, and prudent use of tillage and herbicides are needed to confront herbicide resistance. Agronomic strategies aimed at reducing the time to crop canopy closure represent the foundation of cultural weed control (Jha and Norsworthy 2009). Numerous factors may influence crop canopy development including soil management strategy (i.e., tillage, no-till), planting date, row spacing, seeding rate, soil fertility, herbicide program, and environmental conditions (Arsenijevic et al. 2021; Bradley 2006; Mallarino 1999; Nice et al. 2001; Renner and Mickelson 1997; Yusuf 1999; Zhang et al. 2010). Earlier canopy closure can limit the amount of light reaching the soil surface which impacts weed seed germination, establishment and growth (Norsworthy and Oliveira 2007; Sanyal et al. 2008). Soybean is generally a poor competitor during earlier stages of development, however, early planting and narrow row spacing can improve its competitiveness (Klingaman and Oliver 1994; Legere and Schreiber 1989). In response to widespread herbicide resistance and a shortage of effective POST herbicide options, the use of effective PRE-emergence herbicide programs has increased in frequency for chemical weed control in soybeans. Early-season soybean injury leading to slower canopy closure and potential for yield reduction is a concern of soybean growers adopting effective PRE-emergence herbicides with multiple sites of action (Moomaw and Martin 1978; Niekamp et al. 2000; Nelson and Renner 2001; Osborne et al. 1995; Poston et al. 2008; Sakaki et al. 1991). Research investigating the interaction between cultural agronomic practices and early-season chemical weed control (i.e., PRE-emergence herbicides) on crop canopy development and yield is lacking.

Experiment Overview

In 2019 and 2020 the UW-Madison Cropping Systems Weed Science Lab conducted field experiments evaluating the impact of integrated agronomic and weed management practices on soybean canopy development and yield.

Objective

- Evaluate the impact of integrated agronomic and weed management practices (i.e., planting time, row spacing, tillage practice, and PRE-emergence herbicide application) on soybean canopy development and yield.

Table 1: Monthly average air and soil temperature (4 in depth) and cumulative precipitation at Arlington, Wisconsin.

	Air Temperature[a]			Soil Temperature[a]		Precipitation[a]		
	2019	2020	30 year[b]	2019	2020	2019	2020	30 year[b]
April	45.0	42.0	45.0	47.0	47.2	3.0	1.5	4.4
May	55.2	55.8	58.2	62.8	60.8	6.8	4.4	4.6
June	67.2	70.2	69.0	76.8	77.4	5.6	4.3	5.8
July	75.4	74.6	73.2	85.4	83.8	4.6	5.6	4.5
August	67.8	69.4	71.0	82.2	79.4	6.0	3.8	4.6
September	65.2	58.6	62.4	71.4	71.6	5.7	3.0	3.7
October	44.4	42.4	48.4	62.4	57.8	6.2	0.8	3.1
Season[c]	60.0	59.0	61.0	69.8	68.2	38.0	23.5	30.9

[a] Air and soil temperature reported in F. Precipitation reported as inches. Air, soil and precipitation data obtained from Enviro-weather station (Michigan State University, East Lansing, MI, USA) located at Arlington Agricultural Research Station.

[b] 30-year air temperature and precipitation averages for the period from 1988 - 2018 obtained in R statistical software (version 4.0.1) using daily Daymet weather data for 1 km grids (Thornton et al., 2016; Correndo et al., 2021) ("daymetr" package)

[c] Monthly cumulative precipitation and average temperature throughout the growing season.

[1]Access the journal publication: https://doi.org/10.1017/wet.2021.92

Materials and Methods (Technical Description)

A field experiment was conducted in 2019 and 2020 at the University of Wisconsin-Madison Arlington Agricultural Research Station near Arlington, WI. The experiment was conducted as a four-way-factorial established in a randomized complete block design (RCBD) with four replications. Experimental units were 10 ft wide by 40 ft long. Treatments consisted of two soybean planting times (early planting [late-April] and standard planting [late-May]), two row-spacings (15 in [narrow-row spacing] and 30 in [wide-row spacing]), two tillage systems (no-till and conventional tillage), and PRE-emergence herbicide application (yes PRE and no PRE). The PRE-emergence herbicide used (Fierce® MTZ at 16 fl oz ac^{-1}, Valent U.S.A. LLC, Walnut Creek, CA) has a broad weed control spectrum and is known to cause early-season soybean injury under adverse environmental conditions (i.e., cool and wet soils; Taylor-Lowell et al. 2001; Arsenijevic et al. 2021). The soybean variety AG24X7 (seed treatment; Acceleron® Seed Applied Solutions Elite with NemaStrike^{TM} Technology, Asgrow Seed Co. LLC, Creve Coeur, MO) was planted in both years at 145,000 seeds ac^{-1}, at a depth of 1.5 in. In 2019, soybean was planted on April 25 (early planting) and May 23 (standard planting). The soil type was silt loam (26:59:16; % clay:silt:sand), with a pH of 6.9 and 4.8% of organic matter (OM). In 2020, soybean was planted on April 21 (early planting) and May 22 (standard planting). The soil type was loam (25:48:28; % clay:silt:sand) with a pH of 5.9 and 3.5% OM. No-till corn was the previous crop in both experimental years; the 2019 field was under no-till continuous corn (>5 years) whereas the 2020 field was under no-till corn-soybean rotation (>5 years). PRE-emergence herbicide applications were made the day of each planting to designated plots using a CO_2-pressurized backpack sprayer equipped with Turbo TeeJet® TTI11015 air induction nozzles (Spraying Systems Co., Wheaton, IL) calibrated to deliver 10 gal ac^{-1}. Because the objective of this experiment was to evaluate crop canopy closure and grain yield but not weed suppression, experimental units were kept weed-free throughout the study by hand-weeding and/or glyphosate application when weeds were detected (RoundUp®PowerMax at 32 fl oz ac^{-1}, Bayer AG, Leverkusen, Germany; + ammonium-sulfate at 1.27 lb ac^{-1}). Monthly precipitation, average air and soil temperature (4 in depth) for each year, and historical weather data are presented in Table 1.

To evaluate soybean canopy development, three photos per experimental unit of the six rows (narrow-row spacing) and four rows (wide-row spacing) were taken per week. A wooden L-shape pole (2.1 m height) was constructed, and a GoPro Hero 8 Black camera (GoPro Inc., San Mateo, CA) was mounted at the top and paired with an iPhone 6s cellphone (Apple Inc., Cupertino, CA) through the GoPro App (7.2.1 version), which provided view finding capabilities for the camera. Photos were processed using MATLAB (MathWorks®, Natick, MA) via Canopeo add-on (Canopeo Software, Oklahoma State University, Division of Agricultural Sciences and Natural Resources Soil Physics program, Stillwater, OK; https://canopeoapp.com), which allowed for estimation of fractional green canopy cover within each image (Arsenijevic et al. 2021; Liang et al. 2012; Paruelo et al. 2000; Patrignani and Ochsner, 2015). Soybean canopy development assessments started 7 days after each planting timing and concluded when >95% green canopy cover was attained in all plots throughout the study.

Soybean grain weight (lb plot^{-1}) and moisture (%) were collected at crop physiological maturity (October 26, 2019 and October 15, 2020) with an Almaco plot combine (Almaco, Nevada, IA) by harvesting the two center rows of wide row-spacing treatments, and four center rows of narrow row-spacing treatments. All treatments within a year were harvested at the same time. Yield results were standardized to 13% moisture and converted to bu ac^{-1} for comparisons.

Statistical analysis – R 4.0.1 A 3-parameter Weibull 2 model was fit to average soybean green canopy cover (%; response variable) regressed on the day of the year (Julian day) when photos were taken (explanatory variable) for each experimental unit within each treatment using the “drc” package in R:

$$y = c + (d - c)exp(-exp(b(log(x) - e))) \qquad (1)$$

where y is average soybean green canopy cover (%), c is the lower limit (fixed at 0), d is the upper limit (fixed at 100), b is the slope, x is day of year, and e is the inflection point (Ritz and Strebig 2016). The day of year when 90% soybean green canopy cover (T_{90}) occurred in each plot was estimated using ED function in R. T_{90} results are used herein as an indicator of time for canopy closure. **ANOVA.** Planting time, row-spacing, tillage system, PRE-emergence herbicide and year were treated as fixed effects, and replications nested within years were treated as a random effect. Linear mixed models with a normal distribution (“lme4” package) were fit to T_{90} and yield data. Normality and homogeneity of variance were evaluated using the Pearson chi-square test (“nortest” package) and Levene’s test (“car” package), respectively. T_{90} data were log-transformed and yield data were square-root transformed before analyses to satisfy the Gaussian assumptions of normality and homogeneity of variance. Means were separated when interactions and/or main effects were less than P = 0.05 using Fisher’s protected least-significant difference (LSD). Back-transformed means are presented for ease of interpretation.

Table 2: Estimated day of year when soybean reached 90% canopy closure (T_{90}) according to planting time, year and PRE-emergence herbicide interaction (P = 0.0168).[a]

Planting time[b]	**PRE herbicide**[c]	**T_{90}**	
		2019	2020
		day of year[d]	
Early	No	Jul 14 (± 2 days)*a*	Jul 5 (± 2 days)*a*
	Yes	Jul 18 (± 2 days)*b*	Jul 8 (± 2 days)*b*
Standard	No	Jul 24 (± 2 days)*c*	Jul 8 (± 2 days)*b*
	Yes	Jul 25 (± 2 days)*c*	Jul 13 (± 2 days)*c*

[a] Comparisons of means are split by year. Means within a year followed by the same letter are not different according to Fisher’s LSD test (P = 0.05).

[b] Soybean early planting: (April 2 and 21; 2019 and 2020, respectively); soybean standard planting: (May 23 and 22; 2019 and 2020, respectively). Information in brackets refers to day of year.

[c] Fierce® MTZ at 16 fl oz ac^{-1}.

[d] Parentheses represents lower and upper limits of 95% confidence intervals.

Table 3: Estimated day of year when soybean reached 90% canopy closure (T_{90}) according to planting time, PRE-emergence herbicide and tillage interaction (P = 0.0359).[a]

Planting time[b]	PRE herbicide[c]	T_{90}	
		Conventional tillage	No-till
		———day of year[d]———	
Early	No	Jul 8 (± 2 days)*a*	Jul 13 (± 2 days)*a*
	Yes	Jul 12 (± 2 days)*b*	Jul 15 (± 2 days)*ab*
Standard	No	Jul 16 (± 2 days)*c*	Jul 17 (± 2 days)*b*
	Yes	Jul 17 (± 2 days)*c*	Jul 20 (± 2 days)*c*

[a] Comparisons of means are split by tillage systems for better interpretation. Means within a tillage system followed by the same letter are not different according to Fisher's LSD test (P = 0.05).

[b] Soybean early planting: (April 2 and 21; 2019 and 2020, respectively); soybean standard planting: (May 23 and 22; 2019 and 2020, respectively). Information in brackets refers to day of year.

[c] Fierce® MTZ at 16 fl oz ac^{-1}.

[d] Parentheses represents lower and upper limits of 95% confidence intervals.

Results and Discussion

Soybean Canopy Development (T_{90}). All factors evaluated in this study had an impact on soybean canopy closure. According to the ANOVA results, T_{90} was influenced by planting time × PRE × year (P=0.0168), planting time × PRE × tillage (P=0.0359; Table 2), and the row spacing × year (P=0.0109) interactions. In 2019, early planted soybean reached T_{90} 6-11 days (d) before the standard planted soybean (Table 2). The use of a PRE-emergence delayed T_{90} by 4 d in the early planting whereas it had no impact during the standard planting time. In 2020, early planted soybean within the same PRE-emergence treatment reached T_{90} at 3 to 4 d before the standard planted soybean. The use of a PRE-emergence herbicide delayed T_{90} by 3 to 4 d for both planting times. Under conventional tillage, early planted soybean reached T_{90} at 4 to 9 d before the standard planted soybean (Table 3). The use of a PRE-emergence herbicide delayed T_{90} by 4 d in the early planting whereas it had no impact during the standard planting time. Under no-till, early planted soybean within the same PRE-emergence treatment reached T_{90} 4-5 d before the standard planted soybean. The use of a PRE-emergence herbicide delayed T_{90} by 3 d for the standard planting time. In 2019, narrow row space soybean reached T_{90} 7 d before wide row space (Jul 17 [95% confidence interval; Jul 15 - Jul 19] and Jul 24 [Jul 22 - Jul 26], respectively). In 2020, narrow row space soybean reached T_{90} 4 d before wide row space (day of the year Jul 6 [Jul 4 - Jul 8] and Jul 10 [Jul 8 - Jul 12], respectively). Soybean canopy closure occurred earlier in 2020 compared to 2019, which can be attributed to warmer temperatures in May and June in 2020 compared to 2019 (Table 1). Even though early and standard treatments were planted approximately a month apart, the maximum difference detected in 90% canopy closure was 11 d in 2019. Nevertheless, a 4 to 11 d difference in T_{90} can contribute to cultural suppression of weed species with extended emergence window (i.e., redroot pigweed, waterhemp, Palmer amaranth; Franca 2015; Werle et al. 2014). PRE-emergence herbicide either had no impact or delayed the T_{90} by up to 4 d in this weed-free study. As a caution, DeWerff et al. (2014) reported that soybean canopy development was delayed in treatments where no PRE-emergence herbicide was sprayed and weeds were allowed to compete with the crop.

Soybean Yield. Soybean yield was influenced by the planting time × year interaction (P < 0.0001) and the main effect of tillage (P < 0.0001). PRE-emergence herbicide and row spacing treatments did not influence yield in this experiment (P > 0.05). In 2019, early planted soybean yielded an average of 89.6 bu ac^{-1} (95% confidence interval: 86.8-92.5 bu ac^{-1}) whereas standard planted soybean yielded 76.2 bu ac^{-1} (73.6-78.8 bu ac^{-1}). In 2020, early planted soybeans yielded 62.2 bu ac^{-1} (59.8-64.5 bu ac^{-1}) whereas standard planted soybeans yielded 59.4 bu ac^{-1} (57.1-61.7 bu ac^{-1}). The early planted soybean yielded on average 13.4 bu ac^{-1} and 2.8 bu ac^{-1} more than standard planted soybean in 2019 and 2020, respectively. Even though earlier planted soybeans outyielded standard planted soybeans in both years of this experiment, the yield in 2020 was substantially lower (27% lower). The 2020 growing season exhibited lower precipitation amounts, particularly in August and September (Table 1), where lower observed soybean yield was likely due to decreased soil water availability during the pod-filling phase, a crucial yield development stage (Alessi and Power 1982; Kirnak et al. 2008). In addition, soybeans in 2019 were planted after several years of continuous corn, which likely contributed to a higher yield potential. Treatments under conventional tillage yielded on average 74.6 bu ac^{-1} (72.8-76.5 bu ac^{-1}) whereas treatments under no-till yielded 69.0 bu ac^{-1} (67.3-70.8 bu ac^{-1}), a 5.6 bu ac^{-1} difference. The yield advantage of narrow space soybeans was not observed in this experiment (P = 0.75), contrary to many findings in the literature where narrow-row soybean outyielded widerow soybeans (DeBruin and Pedersen 2008; Lee 2006).**Early planted soybeans closed canopy earlier and yielded more; narrow row spacing closed canopy earlier but did not influence yield; conventional tillage increased soybean yield.** Although PRE-emergence herbicide application slightly delayed canopy development in some treatments, it did not impact yield. PRE-emergence herbicides are an important component of integrated weed management programs and the delay in canopy development if soybeans were allowed to compete with weeds early in the season in the absence of an effective PRE-emergence herbicide would outweigh the slight delay in canopy development by PRE-emergence herbicides observed herein.

Recommendation for Soybean Growers

Enhancing the competitive ability of the cultivated crop early in the season will reduce the weed management efforts required in the remainder of the growing season. Agronomic practices that reduce the time to soybean canopy closure (e.g., earlier planting of narrow soybeans) combined with an effective PRE-emergence herbicide program can contribute to management of troublesome weeds and mitigate further herbicide resistance evolution.

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Authors:
Nikola Arsenijevic, Ryan P. DeWerff, Shawn P. Conley,
Matthew Ruark and Rodrigo Werle

Address:
Department of Agronomy,
College of Agricultural and Life Sciences, University of Wisconsin-Madison

Correspondence:
Rodrigo Werle - rwerle@wisc.edu

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- Residual Control of Waterhemp with PRE-emergence Herbicides in Soybean.
- PRE-emergence Herbicide Selection for Early Planted Soybeans.
- 2021 WiscWeeds Herbicide Comparison for Residual Control in Soybeans on Sandy Soils.
- 2021 WiscWeeds Herbicide Comparison for Residual Weed Control in Corn.

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