Received: 5 June 2024 | Accepted: 16 October 2024

DOI: 10.1002/cft2.70015

Crop, Forage & Turfgrass Management

ORIGINAL ARTICLE

Crop Management

Planting date and maturity groups effects on soybean yield in Wisconsin

Andrew Malcomson | Spyridon Mourtzinis | John Gaska | Adam Roth | Tatiane Severo Silva | Shawn Conley

Department of Plant and Agroecosystem Sciences, University of Wisconsin-Madison, Madison, Wisconsin 53706, USA

Correspondence
Andrew Malcomson, University of Wisconsin Madison, Madison, WI 53706.
Email: amalcomson7@gmail.com

Assigned to Associate Editor Mark Licht.

Funding information
Wisconsin Soybean Marketing Board

Abstract

Soybean [*Glycine max* (L.) Merr.] planting date (PD) and maturity group (MG) selection are critical decisions for optimizing crop development and enhancing yield potential. This study examines the interaction effects of PDs and MGs on soybean yield in southern Wisconsin, utilizing a fractional replication experimental design across two growing seasons (2022 and 2023). Five PDs in 2022 and six in 2023 were tested, with 50 soybean cultivars per PD, encompassing MGs ranging from 0.3 to 2.9. Results reveal that optimal soybean yield occurred with early planting, particularly before May 20, with MGs between 1.5 to 2.9 performing best. Delayed planting led to diminished significance in MG selection for yield, but overall yield declined consistently, roughly 20 bu/acre, every 20 days beyond the May 20 PD. Practical implications suggest early planting to maximize sunlight capture and extend the seed fill period, alongside the selection of cultivars within the appropriate MG range. While this study is limited to a single location and 2-year duration, future collaborative efforts across multiple sites could provide a more comprehensive understanding of PD and MG interactions, benefiting soybean cultivation practices in diverse environments. Overall, our findings offer valuable insights for southern Wisconsin soybean farmers seeking to optimize yield and profitability in their operations.

Plain Language Summary

We looked at how soybean planting date and maturity group affect soybean yield in southern Wisconsin. We conducted experiments over 2 years, trying different planting dates and maturity groups of soybeans. We found that planting soybeans earlier, especially before May 20, generally results in the highest yield, of roughly 80 bu/acre. It's also important to choose the optimum maturity group of soybeans for planting. We noticed that as planting gets delayed, the specific maturity group of soybean

Abbreviations: DOY, Day of the year; MG, maturity group; PD, planting date.

matters less for yield. Farmers can benefit from planting early to make the most of the sunlight and growing season. We also recommend selecting soybean maturity groups that perform well in Wisconsin's climate. This information can help Wisconsin farmers make better decisions for their soybean crops, ultimately leading to high yields and profits.

1 | INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] planting date (PD) and maturity group (MG) selection are important factors for crop development. Earlier soybean planting has been shown to increase seed yield (Mourtzinis et al., 2017). The length of the growing season in Wisconsin has also increased in recent decades leading more farmers to adopt the practice of planting soybeans earlier (WICCI, 2022). However, earlier PDs potentially increases risk from exposure to cold temperatures and pathogens, like *Phytophthora sojae* and *Pythium ultimum* which can cause diseases like root rot, seed rot, and dampening off. These are risks farmers need to consider when planting early.

Soybean cultivars are classified into different MGs to help designate the cultivars into the regions they would be best suited for based upon their length of time to maturity. Soybean breeders have developed 13 total MGs ranging from 000 (earlier maturing cultivars) to 10 (latest maturing cultivars) (Song et al., 2019). Each group can also be divided into tenths to further define the maturity length of a given cultivar. For full-season soybean production in Wisconsin, a 1.5 MG is optimal in the northwest corner of the state, the optimal for the middle of the state is a 2.0 MG, and the southern part of the state is a 2.5 MG (Mourtzinis & Conley, 2017).

Siler and Singh (2022) found that planting a 0.5–1.0 later MG than the optimal for the region, in early PDs, resulted in increased vegetative growth and pod and seed set compared to planting earlier MGs in Michigan. Using a full MG later (+1.0) than what is considered optimal for the region resulted in a yield increase of roughly 7.75 bu/acre across multiple locations with early season planting 120 day of year (DOY; April 30). Their findings concluded that the increased yield from using a later MG came from an increased in the number of seeds per unit area. However, the yield benefits associated with later MGs decreased as soybean planting was delayed. Farmers should aim to use the PD and MG combination that utilizes the entre growing season while avoiding damage from spring or fall frosts (Siler & Singh, 2022). Proper PD and MG timing and selection does not increase production costs and has the potential to maximize yield and profits (Siler & Singh, 2022).

Recent changes in agricultural policies, such as those implemented by the USDA Risk Management Agency, have significant implications for Wisconsin soybean producers. Notably, the earliest soybean PD for full insurance coverage in southern Wisconsin was moved from April 26 to April 15 (Mitchell, n.d.), reducing potential financial risks for early planters. Additionally, the double crop soybean insurance map was expanded to cover most Wisconsin counties, further mitigating financial risks for farmers engaging in double cropping following winter wheat (USDA-RMA, n.d.).

With the increased flexibility in PDs provided by updated insurance policies, farmers can now optimize soybean production by considering various PD and MG combinations tailored to their specific circumstances. For example, pushing PDs earlier than normal or a delayed soybean planting situation if a farmer wants to double crop soybean after wheat (*Triticum aestivum*). This study aims to examine the effects of PDs and MGs on soybean yield in southern Wisconsin.

2 | MATERIALS AND METHODS

2.1 | Site description

Research was conducted at the University of Wisconsin-Madison Arlington Agricultural Research Station near Arlington, WI (Latitude 43°18′9.47″N and Longitude 89°20′43.32″W), during the 2022 and 2023 growing seasons. The 2022 site location coordinates are 43°29′99.27″N and 89°35′02.36″W and the 2023 site coordinates are 43°29′65.27″N and 89°33′82.42″W. The soil is primarily a Plano silt loam, described as a deep and well-drained soil. Soil test data for each site, including pH, phosphorus (P) levels in ppm, potassium (K) levels in ppm, and organic matter percentage, were collected to characterize soil fertility (Table 1).

2.2 | Experimental design

The experimental design was a fractional replication (frac rep) with five soybean PDs in 2022 and six PDs in 2023, as shown in Table 2. An additional PD was introduced in 2023 to explore the impact of early planting practices in Wisconsin. Fractional replication design was used because of the large number of treatments involved. In a fractional replication design, treatments are divided into main plots and sub

TABLE 1 Soil test results in 2022 and 2023.

Year	pH	P (ppm)	K (ppm)	OM (%)
2022	6.5	17	154	2.8
2023	7.2	41	116	3.3

Abbreviation: OM, organic material.

TABLE 2 Soybean planting dates in 2022 and 2023.

Planting date (PD)	2022	2023
1	May 9	April 12
2	May 19	April 28
3	June 10	May 16
4	June 30	June 8
5	July 20	June 29
6	No Additional PD	July 20

plots. The main plots represent the PDs and were replicated, and the subplots represent the individual soybean cultivars within each PD. The main plots were replicated twice within each experiment (year). Some levels of the subplot (MGs) were not replicated.

Within each PD, 50 soybean cultivars were planted with MGs ranging from 0.3 to 2.9. The optimal MG is a 2.5 in southern Wisconsin (Mourtzinis & Conley, 2017). Out of the 50 total cultivars, 40 were planted once, and 10 were planted twice, resulting in 60 total plots per PD. The cultivars were randomly selected from those entered in the Wisconsin Soybean evaluation program in 2022 and 2023 (CoolBean.info, 2024). The same 10 cultivars were planted twice within each PD to increase the robustness of the study and account for potential variability. All soybean cultivars were glyphosate resistant. Supplemental Tables S1 and S2 provide details of the soybean cultivars and MGs for 2022 and 2023, and cultivars in bolded text were planted twice within each PD.

The plots measured 7.5-ft wide and 25-ft long, with soybeans planted in six 15-inch rows at a seeding rate of 140,000 seeds/acre. The established stands were similar across and treatment and in both years. The middle four rows were harvested after reaching the R8 growth stage when moisture content was less than 15% using an Almaco (SPC-40) plot combine to determine yield. All the plots in both years were harvested for yield data and yields were standardized to 13% moisture. Herbicides were applied for post-emergence weed control. Roundup PowerMax (Bayer Crop Sciences) at 32 oz/acre and Warrant (Bayer Crop Sciences) at 48 oz/acre were used in 2022. Roundup PowerMax at 30 oz/acre and Select-Max (Valent) at 10 oz/acre were used in 2023. The choice of herbicides was based on their effectiveness against common weeds in the region.

No significant weed, insect, or disease damage was observed in either year, ensuring minimal interference with the study. The plots were rain-fed, and precipitation data for the growing season (April–October) at Arlington, WI, are presented in Table 3. Average temperature during the growing season (April–October) is presented in Table 4 and the frost dates at the Arlington Agricultural Research Station is presented in Table 5.

2.3 | Statistical analysis

Yield data were subjected to mixed model analysis of variance using PROC GLIMMIX in SAS Version 9.4 (SAS Institute Inc.) separately for each year. Fixed effects included PD (as DOY), MG, their interaction, and quadratic forms. Random effects included replication and variety nested within replication and the overall error term. Degrees of freedom for all analyses were calculated using the Kenward–Rodger method (Littell et al., 2006). Predictions were utilized in PROC SGRENDER to develop visualizations of the effect of planting date and maturity group on soybean yield.

3 | RESULTS

In both years, the optimal PD for soybean seed yield was observed when planting occurred before 140 DOY (May 20). In 2022, MGs ranging between 1.5 to 2.9, averaged 80 bu/acre or more (Figure 1). In 2023, that range was extended to MGs 1.1 to 2.9 and averaged 80 bu/acre or more when planting occurred before 120 DOY (May 20; Figure 1). The difference in MG range between years could be due to differences in cultivars tested or year-to-year variation. Notably, the MG range associated with optimal yield was wider in 2023 compared to 2022, despite experiencing 6.8 inches less rainfall during the growing season (Table 3).

Soybean seed yield declined for late PDs, and the importance of MG selection for soybean yield diminished with delayed planting. For instance, soybeans planted on 160 DOY (June 10) yielded approximately 60–65 bu/acre across the entire MG range of 0.3 to 2.9. Similar results were observed for plantings past June 10.

4 | DISCUSSION

Understanding the theoretical framework behind soybean yield potential is crucial for interpreting our study findings. The number of seeds per unit area and individual seed mass are fundamental factors determining soybean yield (Van Roekel et al., 2015). During soybean development, seed number is primarily determined by canopy photosynthesis rate during flowering and pod set, followed by seed weight determination (Board & Kahlon, 2011; Van Roekel et al., 2015).

TABLE 3 Precipitation during the soybean growing season (April–October) at Arlington Agricultural Research Station near Arlington, WI, in 2022 and 2023.

Year	April	May	June	July	August	September	October	Total
	inches							
2022	2.69	2.30	5.47	2.89	5.19	5.83	1.10	25.47
2023	3.09	1.03	0.93	4.92	4.06	1.75	2.91	18.69
30-Year average	3.55	3.95	5.43	4.06	3.97	3.36	2.62	26.94

TABLE 4 Temperature average during the soybean growing season (April–October) at Arlington Agricultural Research Station near Arlington, WI, in 2022 and 2023.

Year	April	May	June	July	August	September	October
	°F						
2022	41.5	59.6	67.7	71.1	69.1	61.8	49.1
2023	46.3	58.8	68.8	71.1	69.5	65.5	51.7
30-Year average	45.0	57.2	67.3	70.7	68.8	61.8	49.1

TABLE 5 Frost dates at Arlington Agricultural Research Station near Arlington, WI, in 2022 and 2023.

Year	Last spring frost date	First fall frost date
2022	May 4	October 8
2023	April 26	October 19
30-Year average frost date	May 8	October 3

Note: Weather data were obtained from the National Oceanic and Atmospheric Administration database from the Arlington Agricultural Research Station (NOAA National Weather Service, n.d.).

Abiotic and biotic stressors can affect seed size by shortening the effective seed fill period (Egli et al., 1984). Earlier PD and later MG yield increase can likely be explained from a better utilization of photosynthetically active radiation which is a good predictor of soybean seed yield (Gaspar & Conley, 2015). Ort et al. (2022) found that factors such as warmer temperatures, adequate precipitation during all growth stages, and longer photoperiod led to increased soybean yield.

Our study revealed a consistent decline in soybean yield with delayed PDs past 140 DOY (May 20). This decline can be attributed to a lower total canopy photosynthesis rate and a shortened seed fill period associated with delayed planting. Additionally, early planting allows for more vegetative growth before flowering due to soybean photoperiod sensitivity. This results in more nodes and potentially larger plants, which may contribute to higher yield potential. Despite experiencing 6.8 inches less rainfall in 2023 compared to 2022, soybean yields remained comparable for both years. This suggests that the drought in May and June did not significantly affect yields, possibly because it occurred before the critical seed fill period had begun and because the soil at the Arlington Agriculture Research Station has a large water holding capacity and had a wetter than normal root zone soil moisture level going into the 2023 growing season (NASA Grace, 2024).

The reproductive development of soybean, triggered by the length of the night, influences PD effects (Conley et al., 2018). Delayed planting initiates reproductive development sooner, this resulted in similar yields across all MG (0.3–2.9) when planting occurred past 160 DOY (June 10). This is consistent with recent research conducted across the state of Louisiana (Moseley et al., 2024). Overall, our findings highlighted two key trends: a consistent decline in soybean yield as PDs were delayed and similar yields across different MGs as planting was delayed. This is supported from research by Mourtzinis et al. (2017), which emphasized the importance of late April to early May planting and the use of a 2.5 MG for maximizing soybean seed yield. Based on our findings, southern Wisconsin farmers can use an earlier MG soybean (1.5 and above) without a negative yield effect on full season soybean production.

Practical implications for southern Wisconsin soybean farmers include maximizing sunlight capture and extending the seed fill period by planting as early as possible. Additionally, cultivars within the appropriate MG range for each region of Wisconsin (1.5 MG in the northwest, 2.0 MG in central, and 2.5 in the south) is essential. While our results indicate a wide range of MG options, the significance of MG selection on yield diminished when planting occurred past June 10 (160 DOY). In delayed planting situations (past the 160 DOY), southern Wisconsin farmers should consider planting an earlier MG (1.5 or earlier) to reduce their risk of the soybean not developing in time to be harvested.

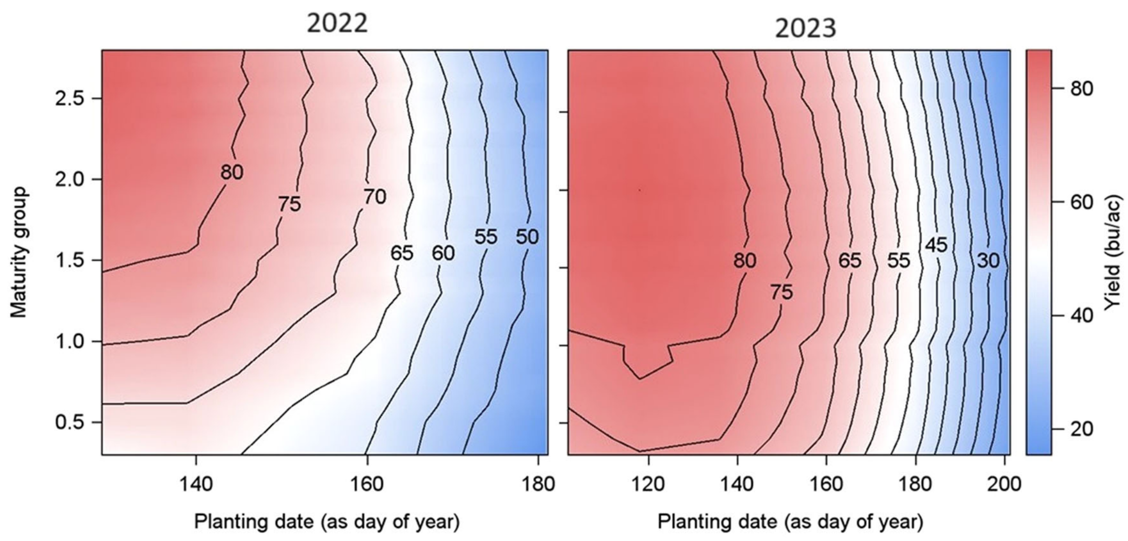

FIGURE 1 Effect of planting date (as day of year on *x*-axis 120 day of year [DOY] is May 20) and maturity group (*y*-axis) on soybean yield (bu/ac) in 2022 and 2023. Red shows combination of planting dates and maturity groups that resulted in high yield and blue with lower yield.

5 | RECOMMENDATIONS

Our study highlights the importance of PDs and MGs on soybean yield in Wisconsin. Planting before May 20 consistently resulted in higher yields, with MGs ranging from 1.5 to 2.9 also resulting in the highest yield. Delayed planting led to decreased importance of MG selection for soybean yield. However, planting an earlier MG in delayed planting situation is recommended to avoid frost damage. Practical implications suggest early planting to maximize sunlight capture and extend the seed fill period. Also, selecting cultivars within the appropriate MG range for each region of Wisconsin (1.5 MG in the northwest, 2.0 MG in central, and 2.5 in the south). Acknowledging study limitations, including its single-location and 2-year duration, future collaborative research efforts across multiple sites could offer a more comprehensive understanding of PD and MG interactions. In conclusion, our findings provide valuable guidance for Wisconsin soybean farmers aiming to enhance yield and profitability in their operations.

AUTHOR CONTRIBUTIONS

James Malcomson: Data curation; investigation; writing—original draft. **Spyridon Mourtzinis**: Data curation; formal analysis; writing—review and editing. **John Gaska**: Data curation; investigation; methodology; resources. **Adam Roth**: Data curation; investigation; methodology; resources. **Tatiane Severo Silva**: Resources; writing—review and editing. **Shawn P. Conley**: Conceptualization; funding acquisition; project administration; resources; supervision; writing—review and editing.

ACKNOWLEDGMENTS

The authors thank the Wisconsin Soybean Marketing Board for funding the research.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ORCID

Andrew Malcomson https://orcid.org/0009-0002-8787-9347

Spyridon Mourtzinis https://orcid.org/0000-0002-7302-5482

Shawn Conley https://orcid.org/0000-0002-8413-1088

REFERENCES

Board, J. E., & Kahlon, C. S. (2011). Soybean yield formation: What controls it and how it can be improved. In H. El-Shemy (Ed.), *Soybean physiology and biochemistry* (pp. 1–36). InTech Open. https://www.intechopen.com/chapters/22761

CoolBean info. (2024). *Variety trial results*. CoolBean Info. https://coolbean.info/soybean-research/variety-trial-results/

Conley, S. P., Chamberlain, L., & Specht, J. (2018). *Soybean flowering fallacy*. CoolBean.info. https://coolbean.info/wp-content/uploads/sites/3/2017/10/2018_Soybean_flowering_final.pdf

Egli, D. B., Orf, J. H., & Pfeiffer, T. W. (1984). Genotypic variation for duration of seedfill in soybean. *Crop Science*, *24*(3), 587–592. https://doi.org/10.2135/cropsci1984.0011183İ002400030037x

Gaspar, A. P., & Conley, S. P. (2015). Responses of canopy reflectance, light interception, and soybean seed yield to replanting suboptimal stands. *Crop Science*, *55*(1), 377–385. https://doi.org/10.2135/cropsci2014.03.0200

Littell, R. C., Milliken, G. A., Stroup, W. W., Wolfinger, R. D., & Schabenberger, O. (2006). *SAS For mixed models* (2nd ed.). SAS Institute.

NASA Grace. (2024). *Map archive*. https://nasagrace.unl.edu/Archive.aspx

Mitchell, P. (n.d.). *Crop insurance changes for 2023*. Farm Management.

Moseley, D., Reis, A., Gentimis, T., Campos, P., Copes, J., Netterville, M., Egbedi, P., Harrell, D., Kongchum, M., Levy, R., Padgett, B., Soignier, S., Scroggs, D., Sanders, J., Pankey, J., & Fic, K. (2024). Soybean planting dates and maturity groups: Maximizing yield potential and decreasing risk in Louisiana. *Agronomy Journal*, *116*(5), 2174–2185. https://doi.org/10.1002/agj2.21626

Mourtzinis, S., & Conley, S. P. (2017). Delineating Soybean Maturity Groups across the United States. *Agronomy Journal*, *109*(4), 1397–1403. https://doi.org/10.2134/agronj2016.10.0581

Mourtzinis, S., Gaspar, A. P., Naeve, S. L., & Conley, S. P. (2017). Planting date, maturity, and temperature effects on soybean seed yield and composition. *Agronomy Journal*, *109*(5), 2040–2049. https://doi.org/10.2134/agronj2017.05.0247

NOAA National Weather Service. (n.d.). *Climate*. https://www.weather.gov/wrh/climate?wfo=mkx

Ort, N., Morrison, M., Cober, E., McAndrew, D., & Lawley, Y. (2022). A comparison of soybean maturity groups for phenology, seed yield, and seed quality components between eastern Ontario and southern Manitoba. *Canadian Journal of Plant Science*, *102*(4), 812–822. https://doi.org/10.1139/cjps-2021-0235

Siler, T. B., & Singh, M. P. (2022). Optimal soybean maturity group selection is influenced by planting date in northern production systems. *Crop Science*, *62*(6), 2462–2475. https://doi.org/10.1002/csc2.20829

Song, W., Sun, S., Ibrahim, S. E., Xu, Z., Wu, H., Hu, X., Jia, H., Cheng, Y., Yang, Z., Jiang, S., Wu, T., Sinegovskii, M., Sapey, E., Nepomuceno, A., Jiang, B., Hou, W., Sinegovskaya, V., Wu, C., Gai, J., & Han, T. (2019). Standard cultivar selection and digital quantification for precise classification of maturity groups in soybean. *Crop Science*, *59*(5), 1997–2006. https://doi.org/10.2135/cropsci2019.02.0095

USDA-RMA. (n.d.). *Double cropping initiative*. https://rma.usda.gov/en/Topics/Double-Cropping-Initiative

Van Roekel, R. J., Purcell, L. C., & Salmerón, M. (2015). Physiological and management factors contributing to soybean potential yield. *Field Crops Research*, *182*, 86–97. https://doi.org/10.1016/j.fcr.2015.05.018

Wisconsin Initiative on Climate Change Impacts (WICCI). (2022). *2021 Assessment report: Understanding climate change in Wisconsin*. Wisconsin Initiative on Climate Change Impacts. https://wicci.wisc.edu/2021-assessment-report/

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Malcomson, A., Mourtzinis, S., Gaska, J., Roth, A., Silva, T. S., & Conley, S. (2024). Planting date and maturity groups effects on soybean yield in Wisconsin. *Crop, Forage & Turfgrass Management*, *10*, e70015. https://doi.org/10.1002/cft2.70015