Planting Date, Maturity, and Temperature Effects on Soybean Seed Yield and Composition

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In a bean pod:

- Planting Date (PD) × Maturity Group (MG) decisions can greatly affect soybean seed yield and composition.
- Temperature between R5-R8 had a significant effect on the resulting soybean seed yield and composition.
- Early planting (late April to early May) and using the longest maturity group (MG 2) was associated with the highest yield, oil, and oleic acid potential but with lower protein and linolenic acid.
- If a seed with high protein content is the over-arching goal, a compromise in lower seed yield may be necessary.
- Soybean producers should modify the growing environment depending on their product's end use (e.g., high yield vs. high protein), by selecting appropriate PDs and MGs for their respective regions.

Introduction

Soybean maturity selection is an important management decision. Maturity group (MG) zones represent regions where a cultivar is best-adapted without implying that MG-specific cultivars cannot be grown elsewhere (Boerma and Specht, 2004). Most recently, Mourtzinis and Conley (2017) redelineated MG zones across the U.S. using 2005-2015 yield variety trial data. In their study, although the zones were generated using a vast amount of information, the results are restricted to the planting date (PD) range of the variety trials.

While early planting is a prudent management practice to increase soybean yield (Gaspar and Conley, 2015), logistical, equipment, environment, and labor challenges can delay planting. However, when early planting is possible, soybeans are exposed to a greater risk of a spring killing frost, early season insects and seedling diseases, and damaging rainfall events that may result in sub-optimal stand. In such years, replanting may be necessary. Furthermore, the climate variability that is affecting state and regional soybean yields (Mourtzinis et al., 2015) may also cause more frequent replanting situations. Therefore, growers would benefit economically from data outlining the proper MG range to use depending upon the PD, to maximize yield and avoid fall frost damage in their respective latitudinal zone.

Soybean seed contains protein and oil and depending on the end use, other important constituents such as specific amino acids (nutritionally essential and non-essential), non-protein-based amino acids, sugars, and fatty acids whose relative concentration contributes to oil stability. Sugars, such as sucrose, raffinose, and stachyose, are also important since their relative concentrations contribute to flavor, taste, and digestibility of feed (Bellaloui et al., 2015). The value of the crop has long been based on the seeds' relatively high protein and oil content. Currently cultivated varieties planted in Wisconsin contain approximately 30-40% protein and 15-20% oil (Roth et al., 2014). The effect of the production location has possibly the greatest influence, where soybeans grown in the northern Corn Belt are consistently lower in protein compared to those grown in southern states (Rotundo et al., 2016). Many underlying weather and environmental factors have been suggested to explain this variation, including differences in temperature throughout the growing season (Yaklich and Vinyard, 2004).

In the northern U.S., both MG and PD affect the environment in which soybeans progress from R5-R7 (seed fill). Therefore, the objectives of this study were to (1) determine the MG × PD range that maximizes seed yield, and (2) quantify the effects of temperature during R5-R8 (T5-8) on soybean seed composition characteristics in the northern Corn Belt.

Materials and Methods

Field trials were conducted at four agricultural research stations located at different latitudes from southern Wisconsin, central WI, and Minnesota through northern WI during 2014, 2015, and 2016 resulting in 12 environments (year × location). The trials included five PDs targeted at May 1st, May 20th, June 1st, June 10th, and June 20th and two varieties that were targeted at MGs 2.0, 1.5, 1.0, and 0.5. Seed yield was computed by adjusting moisture to 13%. A grain sub-sample was collected for each plot during harvest and analyzed for protein, oil, 18 amino acids (cysteine, lysine, methionine, threonine, tryptophan, alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, proline, serine, isoleucine, leucine, phenylalanine, valine, and tyrosine), oleic, linoleic, linolenic, palmitic and stearic fatty acids, raffinose, stachyose, and sucrose contents. The average environment-specific air temperatures between R5-R8 were also recorded from weather stations near each experimental site. Univariate and multivariate response surface methodology was used to examine the effect of PD as a day of the year, MG, and their interaction on seed yield and composition.

Results and Discussion

Planting Date × Maturity Group Effects

Across the examined region, large yield variability was observed due to PD and MG combinations (Fig. 1 A). The figure shows the yield response for several PD×MG combinations and shows that the greatest seed yield resulted from early planting (late April to early May) and MG 2.

This result agrees with the highest-yielding MG identified by Mourtzinis and Conley (2017) for the same region. In that study, MG 1.4-2.2 resulted in the highest yields in Spooner and Arlington, WI, the northernmost and southernmost sites of the study, respectively. For MG 2, a 18 bu/ac yield difference was observed between early and late PDs. Similar yield losses due to delayed planting have been reported by other studies in the region (Conley et al., 2012; Gaspar and Conley, 2015). For shorter season MGs, such as a 0.5, PD had little effect on yield, but the maximum was only 75% of the late MG's planted early. There are situations in which early planting is not possible due to weather constraints, but there must be large economic benefits associated with agronomic practices that may delay soybean planting such as fall planted cover crops since early planting with a longer MG has no additional inputs costs associated with the increased yield potential. Maturity group selection and PD are simple and yet important management decisions that should not be separate across the examined region.

Planting date and MG selection were important factors for soybean seed protein and oil content and their sum (Fig. 1 B-D). Late planting of all MGs resulted in the greatest protein concen-

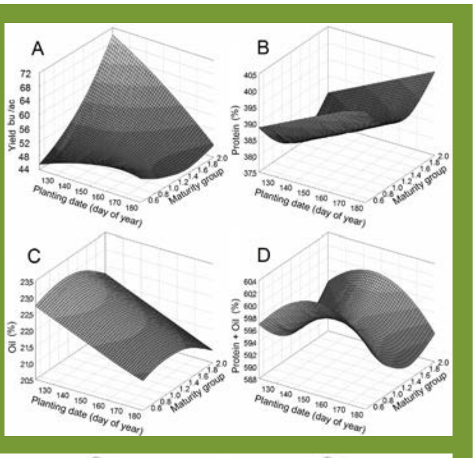

Figure 1. **Planting Date x Maturity Group** (as day of year) response surface of:

A) Yield (bu/ac)

B) Protein (%)

C) Oil (%)

D) Protein+Oil (%)

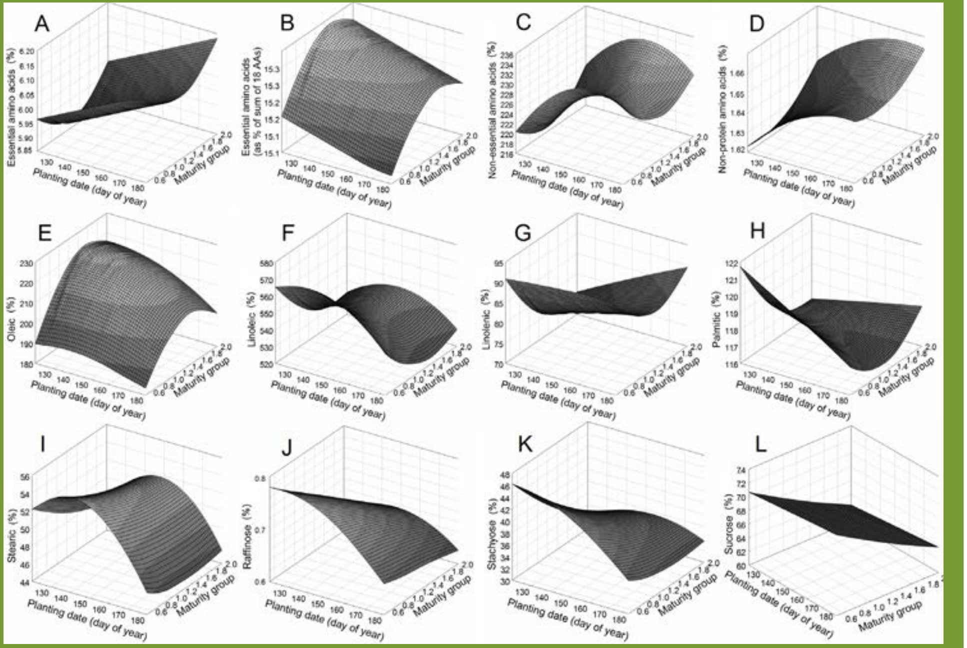

Figure 2. **Planting Date x Maturity Group** (as day of year) response surface of:

A) Sum of essential amino acids (%)

B) Sum of essential amino acids (as % of the sum of 18 amino acids)

C) Sum of non-essential amino acids (%)

D) Sum of non-protein amino acids (%)

E) Oleic acid (%)

F) Linoleic acid (%)

G) Linolenic acid (%)

H) Palmitic acid (%)

I) Stearic acid (%)

J) Raffinose (%)

K) Stachyose (%)

L) Sucrose (%)

trations. The opposite response was observed for oil content in that early planting resulted in the greatest oil amount. Both protein and oil were affected mainly by PD and to a lesser degree, by MG. Because of the inverse relationship of protein and oil, the response curve for the sum was curvilinear across PD and showed a maximum at mid-May PDs. These results suggest that a single combination of management practices with the goal of maximizing soybean yield, protein, and oil content may be difficult to attain. Planting a MG 2 in early May was found to maximize seed yield and oil content, but it resulted in the lowest observed protein content.

Soybean seed constituents respond to PDs and MGs in complex ways (Fig. 2). For example, essential amino acids follow the same response as protein to the PD × MG combinations we tested (Fig. 2 A). However, their sum, as a percentage of total 18 amino acids, follows the opposite trend (Fig. 2 B). Additionally, the concentrations of the five fatty acids exhibited different responses to variable PD × MG combinations (Fig. 2 E-I), whereas sugar content responses were similar (Fig. 2 J-L). Early planting was associated with lower protein and linolenic acid, and higher oil, oleic acid, and sugar contents. These findings further highlight the complexity of the impact of soybean management on seed composition; PDs and MGs should be chosen based on the product's end use (yield vs. seed composition).

Temperature × Maturity Group Effects

Across all environments included in the study, and depending on the PD, T5-8 ranged between 57 and 72°F. The negative correlation between T5-8 and PD (r= -0.39, P<0.0001) indicates that earlier planting resulted in warmer average air temperatures between R5-R8. It appears that these warmer temperatures favored yields of later-maturing soybeans (Fig. 3 A) whereas, it slightly suppressed yields of MG 0.5-1.

Temperature variability, which was introduced to this study through PDs, also affected soybean composition. Increased T5-8 reduced protein (Fig. 3 B) and favored oil (Fig. 3 C) and P+O (Fig. 3 D) contents. Additionally, increased T5-8 reduced essential (Fig. 4 A), non-essential (Fig. 4 C), and non-protein (Fig. 4 D) amino acids, as well as linoleic (Fig. 4 F) and linolenic (Fig. 4 G) fatty acids. However, the relative concentration of essential amino acids as a percentage of the sum of 18 amino acids (Fig. 4 B), oleic (Fig. 4 E) and stearic (Fig. 4 I) fatty acids, and sugars contents (Fig. 4 J-L) were increased due to the elevated T5-8.

Overall, data suggest that T5-8 had a significant effect on the resulting soybean seed yield and composition. We found multiple constituents that showed a large variability in their responses to management decisions and temperature variations. Our findings highlight the importance of soybean producers understanding their product's end use (e.g., high yield vs. high protein and combinations), and modifying the growing environment accordingly by selecting appropriate PDs and MGs for their respective regions.

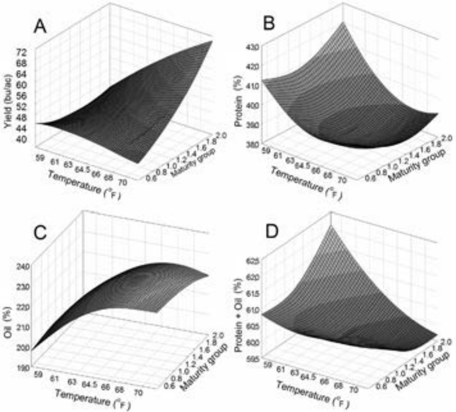

Figure 3. Air Temperature x Maturity Group between R5 and R8 growth stages response surface of:

A) Yield (bu/ac)

B) Protein (%)

C) Oil (%)

D) Protein+Oil (%)

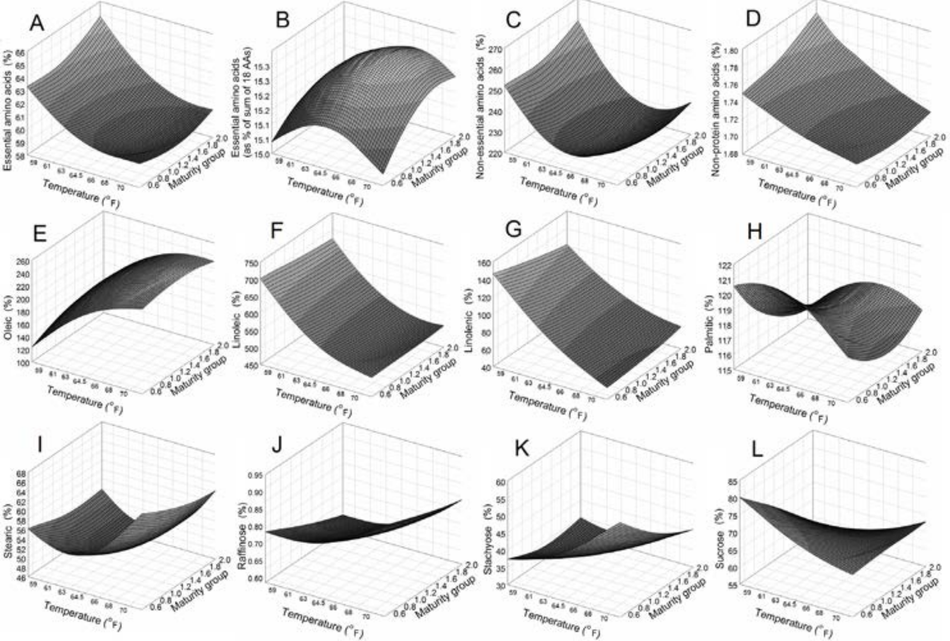

Figure 4. Air Temperature x Maturity Group between R5 and R8 growth stages response surface of:

A) Sum of essential amino acids (%)

B) Sum of essential amino acids
(as % of the sum of 18 amino acids)

C) Sum of non-essential amino acids (%)

D) Sum of non-protein amino acids (%)

E) Oleic acid (%)

F) Linoleic acid (%)

G) Linolenic acid (%)

H) Palmitic acid (%)

I) Stearic acid (%)

J) Raffinose (%)

K) Stachyose (%)

L) Sucrose (%)

Conclusions

The work presented here shows that planting date and MG decisions can greatly affect yield and composition, and therefore, significantly increase or suppress overall farm profitability. Combination of early planting (late April to early May) and using the longest maturity group (MG 2) had the highest yield, oil, and oleic acid potential across the examined region. However, if a seed with high protein content is the overarching goal, a compromise in lower seed yield may be necessary.

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References

Boerma, H.R., and J.E. Specht, editors. 2004. *SOYBEANS: Improvement, Production, and Uses*. Third Edition: (Eds), American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, USA, 2004, 1144 pp. http://dx.doi.org/10.1016/j.agsy.2004.06.006

Bellaloui, N., Bruns, H.A., Abbas, H.K., Mengistu, A., Fisher, D.K., and K.N. Reddy. 2015. *Agricultural practices altered soybean seed protein, oil, fatty acids, sugars, and minerals in the Midsouth USA.* Front Plant Sci. 2015; 6: 31. doi: 10.3389/fpls.2015.00031.

Conley, S.P., E.M. Cullen, V. Davis, P. Esker, and C. Laboski. 2012. *Soybean yield limiting factors in Wisconsin*. Coop. Ext. Serv. Univ. of Wisconsin–Madison.

Gaspar, A.P. and S.P. Conley. 2015. *Responses of canopy reflectance, light interception, and soybean seed yield to replanting suboptimal stands.* Crop Sci. 15:377-385.

Mourtzinis, S., and S. P. Conley. 2017. *Delineating Soybean Maturity Groups Across the US.* Agron. J. 109:1–7. doi:10.2134/agronj2016.10.0581.

Mourtzinis, S., J.E. Specht, L.E. Lindsey, W.J. Wiebold, J. Ross, E.D. Nafziger, H.J. Kandel, N. Mueller, P.L. Devillez, F.J. Arriaga, and S.P. Conley. 2015. *Climate-induced reduction in US-wide soybean yields underpinned by region- and in-season specific responses.* Nature Plants 1, Article no.:14026. doi: 10.1038/plants.2014.26.

Roth, A.C., S.P. Conley, and J.M. Gaska. 2014. *Wisconsin soybean variety test results.* Coop. Ext. Serv. A-3654. Univ. of Wisconsin-Madison, Madison, WI.

Rotundo, J.L., J.E. Miller, and S.L. Naeve. 2016. *Regional and temporal variation in soybean seed protein and oil across the United States.* Crop Sci. 56:797–808.

Yaklich, R., and B. Vinyard. 2004. *A method to estimate soybean seed protein and oil concentration before harvest.* JAOCS. 81:1021-1027.