Identifying Optimum Planting Populations for Midwestern US Food-Grade Soybean Production

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Introduction

- Soybean [*Glycine max* (L.) Merr.] grown for direct human consumption is an increasing market in the U.S. driven by demand for soy-based products and price premiums[1].
- Food-grade soybean is used to produce several soy-foods including tofu, soymilk, edible oil, and natto.
- Compared to commodity soybean production, food-grade soybean production places extra emphasis on quality rather than quantity alone[2].
- Due to the difference in end use, agronomic practices recommended to commodity soybean producers may differ from those to food-grade soybean producers.
- Current planting population recommendations for food-grade soybean producers in the Midwestern US are equal to or greater than recommended populations for commodity soybean producers, depending on variety.
- However, high planting populations increase production cost and has been shown to increase the potential for plant lodging and diseases such as white mold [*Sclerotinia sclerotiorum* (Lib.) de Bary][3].

Objectives

- Determine optimum planting populations for food-grade soybean varieties.
- Compare and contrast planting populating response of food-grade soybean varieties to commercial varieties.
- Correlate quality parameters in food-grade soybean to yield.

Methods

- Field experiments were conducted in 2018 and 2019 at East Lansing, MI (76-cm row spacing) and Saginaw, MI (38-cm row spacing). Results from 2018 are presented.
- Six soybean varieties (Table 1) were planted at six planting populations ranging from 123,500 - 741,000 seeds ha^{-1} and set up in a RCBD with four replications.

Table 1. Variety name, source of seed, maturity group (MG), seed size (g 100 seeds^{-1}), and seed type for each variety used in this study. MSU refers to Michigan State University's soybean breeding program.

Variety	Source	MG	Seed Size	Type
E16603	MSU	1.8	7.9	Natto
E13100-3	MSU	2.5	21.1	Tofu
E12076-T	MSU	2.9	16.5	Conventional
E17801-10	MSU	2.9	14.0	High-Oleic
P20T53PR	Pioneer®	2.0	14.2	High-Oleic
GH2041X	Golden Harvest®	2.0	19.2	Commodity

- Final yield was determined using a plot combine to harvest the center two or four rows of each plot, depending on row spacing.
- Quality analysis was preformed with a field collected sub -sample using a FOSS NIRS™ DS2500 F.
- Aside from protein and oil content, additional quality parameters being analyzed include sugar and fatty acid profiles, water imbibition, and seed uniformity.
- Data was analyzed using Proc Glimmix with Tukey's adjustment in SAS at α=0.1.

Results

Yield

- Changes in planting population had no effect on yield for both high oleic-type varieties at either location (data not presented).
- A planting population of 123,500 seeds ha^{-1} resulted in reduced yields for the conventional-type (Figure 1) and GMO-type (Figure 2) varieties at both locations.

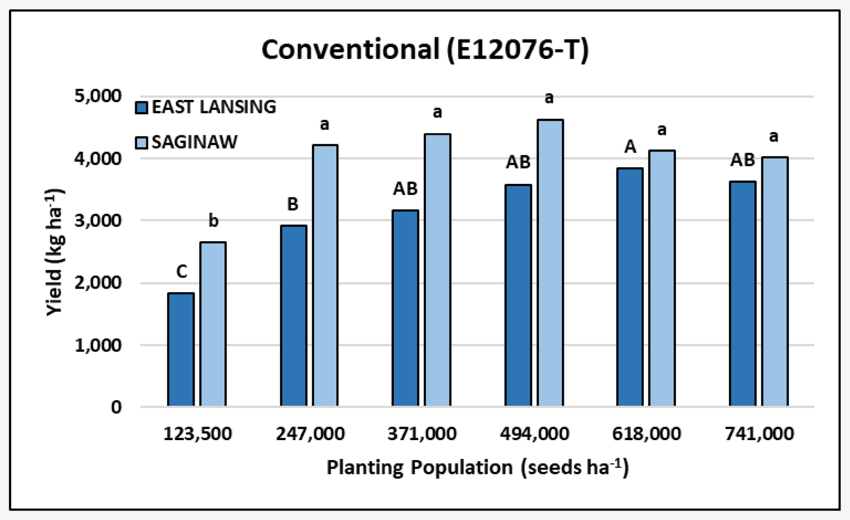

Figure 1. Effect of planting population on seed yield for conventional (E12076-T) variety at East Lansing (P<0.001) and Saginaw (P=0.001). Bars with the same case letters are not different at P<0.1.

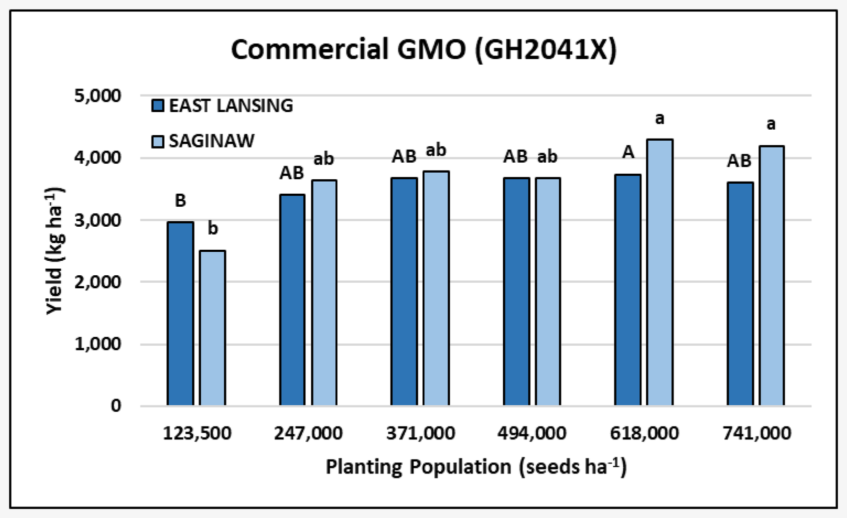

Figure 2. Effect of planting population on seed yield for commercial GMO (GH2041X) variety at East Lansing (P=0.09) and Saginaw (P=0.02). Bars with the same case letters are not different at P<0.1.

- Yield was reduced for natto-type (Figure 3) and tofu-type (Figure 4) varieties when a planting population of 123,500 seeds ha^{-1} was used at Saginaw and East Lansing, respectively.

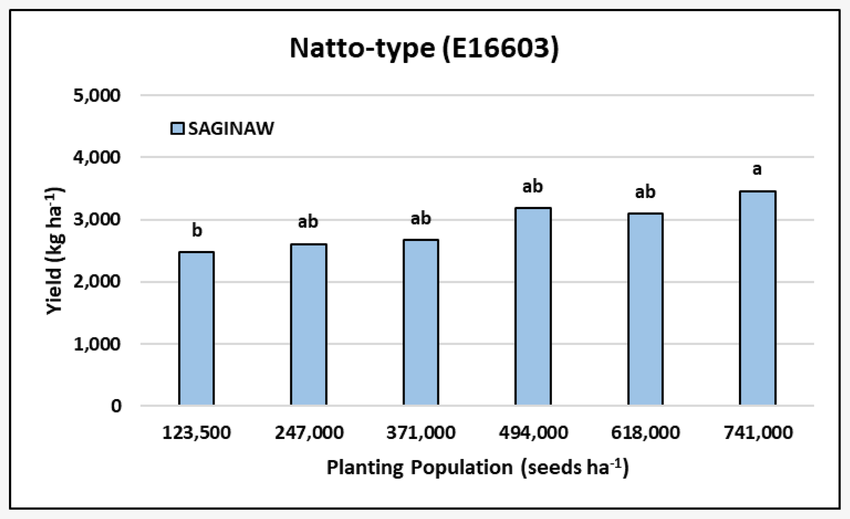

Figure 3. Effect of planting population on seed yield for natto-type (E16603) variety at Saginaw (P=0.05). Bars with the same letter are not different at P<0.1.

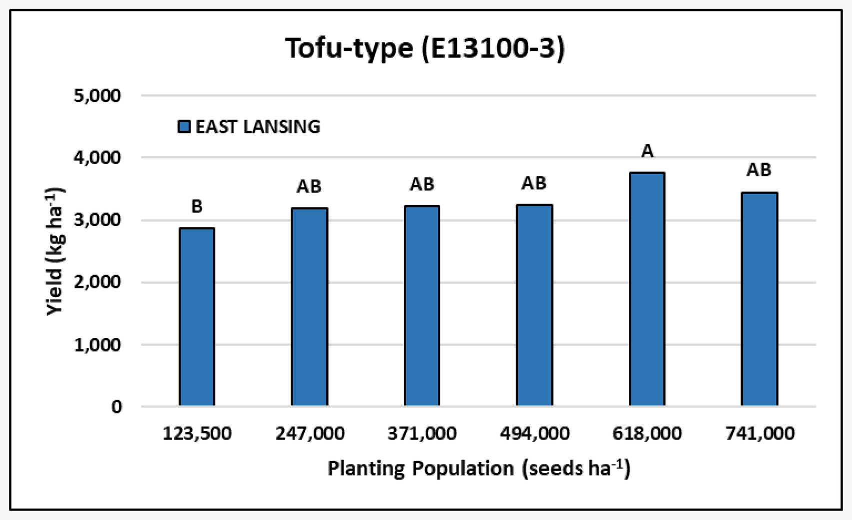

Figure 4. Effect of planting population on seed yield for tofu-type (E13100-3) variety at East Lansing (P=0.02). Bars with the same letter are not different at P<0.1.

Quality

- Soybean oil and protein content showed a limited response to changes in planting population (data not presented).
- Compared to commercially available varieties, varieties from MSU's breeding program showed weaker correlations between yield and quality parameters.
- At Saginaw, correlation between yield and quality parameters was limited to the commercially available commodity-type variety where protein was positively correlated with yield (r=0.44, P=0.03).

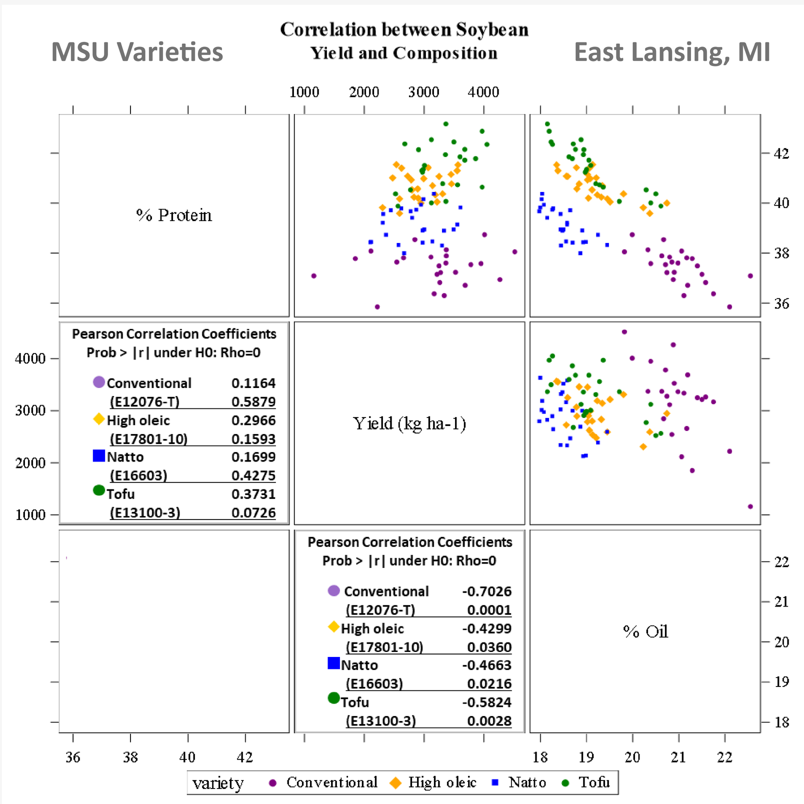

Figure 5. Correlation between yield, protein, and oil for four MSU food-grade varieties. Correlation coefficient and P-value for each variety is listed in each table corresponding to table's axes.

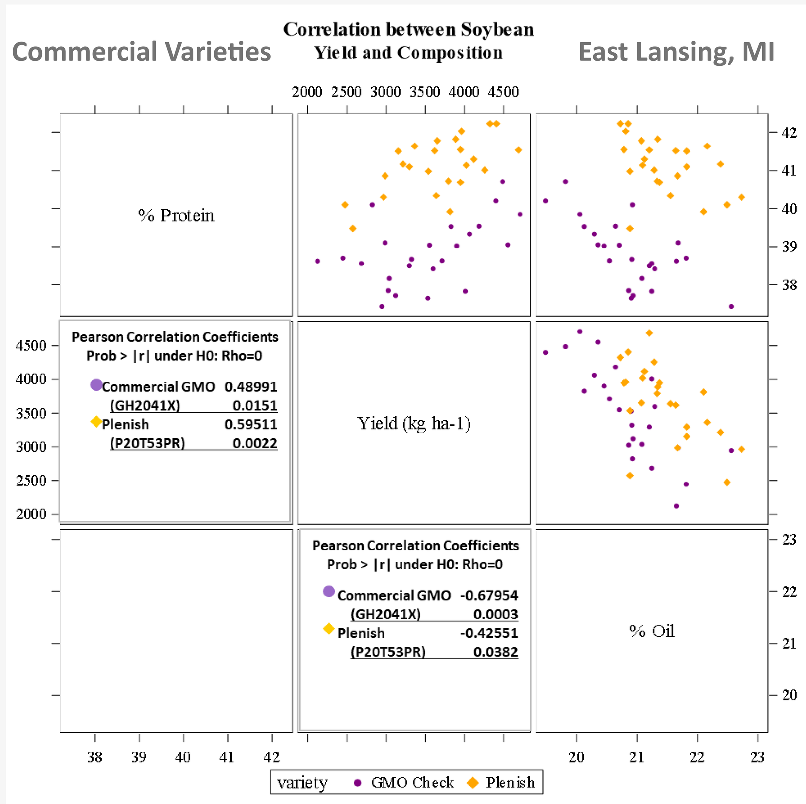

Figure 6. Correlation between yield, protein, and oil for two commercially available varieties. Correlation coefficient and P-value for each variety is listed in each table corresponding to table's axes.

- No correlation between yield and protein content was observed for any MSU food-grade varieties (Figure 5).
- MSU food-grade varieties showed a negative correlation between oil content and yield (Figure 5).
- Both commercially available varieties showed a positive correlation between protein content and yield as well as a negative correlation between oil content and yield (Figure 6).

Seed Size

Figure 7. Food-grade soybean varieties are often defined by seed size and end use. Small-size soybean (left plate) is often used for natto which is fermented and eaten whole. Large-size soybean (right plate) is often used for tofu and soymilk. Middle plate showing regular-size soybean for comparison.

Plant Architecture

Figure 8. Left picture showing natto-type variety planting at low planting population. Right picture showing natto-type variety planted at high planting population. Differences in stem diameter, branches, and height of lowest pod on the plant can be observed.

Conclusion

- Soybean response to planting population changes is variable and dependent on variety, environment, and row spacing.
- A planting population as low as 371,000 seeds ha^{-1} did not impact yield compared to higher planting populations for all varieties used in this study.
- Increased yield did not correlate with increased protein content for MSU food-grade varieties, but commercially available varieties showed a positive correlation between yield and protein content.
- Oil content was negatively correlated with yield for all varieties used in this study at East Lansing.
- These results show evidence that food-grade soybean varieties respond differently to agronomic practices compared to commercial varieties.
- The limited yield reduction, reduced input costs, and increased potential to reduce soybean disease and lodging associated with lower planting populations implies food-grade soybean produces may benefit from using planting populations lower than what is currently recommended.
- Establishing optimum planting populations for food-grade varieties is the first step in developing unique guidelines for food-grade soybean production.
- Future research will focus on identifying additional management practices that improve yield and profits, mitigate disease and stress, and enhance quality.

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