Break-Even Profitability for Food-Grade Specialty Soybeans

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DOI: 10.12735/as.v2i2p01

Abstract

Cultivar selection for specialty soybeans is mainly based on seed-yield performance, disease resistance, and value-increasing seed attributes. However, adoption of food-grade specialty soybean cultivars by farmers for commercial production requires studies on profitability and economic factors. This research evaluated the profitability of small-seeded, large-seeded, and high-protein specialty soybeans using break-even (BE) analysis to establish guidelines for cultivar selection and adoption based on economic feasibility. Differential costs for seed and weed control were considered in the BE analysis of two different planting systems: conventional (Scenario I) and herbicide tolerant (Scenario II) soybeans. Average BE premiums were $2.74, $4.26, and $1.30 bu\(^{-1}\) under Scenario I, and $2.02, $4.57, and $0.66 bu\(^{-1}\) under Scenario II for small seeded, large seeded, and high-protein test lines, respectively. At current premium level of $3.50 bu\(^{-1}\) for small seeded, $2.50 bu\(^{-1}\) for large seeded, and $1.50 bu\(^{-1}\) for high-protein specialty soybean, BE yields for these three types of specialty soybean should be 76.46, 85.21, and 89.28% of the check’s yield when compared with conventional soybean; and 77.47, 92.92, and 90.71% of the check’s yield when compared with Roundup Ready soybean, respectively. Additional positive returns will be expected when the current premiums offered in the market are higher than the BE premium of a specialty soybean cultivar, or when the actual yields of this cultivar are higher than the BE yield at current premiums. Based on the economic feasibilities, the present study proposed a new model for the selection and adoption of specialty soybean cultivars, both in breeding programs and for commercial production.

Keywords: specialty soybean, premiums, yield, large seeded, high protein

Abbreviations: ASRVP, Arkansas Soybean Research Verification Program. ASPT, Arkansas Soybean Performance Test. BE, break-even. USDA-NASS, United States Department of Agriculture
1. Introduction

Soybean is the number one value crop in the United States for export and the second largest crop following corn in cash sales. After a steady increase in the last two decades, the planting acreage of soybeans soared to a new record of 31.4 million hectares in 2009 and has remained over 30.0 million hectares during the last five years (United States Department of Agriculture – National Agricultural Statistics Service [USDA-NASS], 2013). With the rapid expansion of soybean production around the world, competition in global soybean trade imposes new challenges to conventional commodity cropping systems. Lower production costs and comparable technologies are just a few results of worldwide production competitiveness (Paz, Batchelor, & Jones, 2003; Lambert & Lowenberg-DeBoer, 2003). Additionally, utilizing new ways to add value to commodity soybean (e.g., planting of food-grade specialty soybeans) could improve profitability and competitiveness in the world market (Fernandez-Cornejo, Wechsler, Livingston, & Mitchell, 2014).

Food-grade specialty soybeans are used for tofu, soy milk, edamame, natto, soybean sprout, and for the processing of other soy-food products tailored for human consumption. Changes in consumers’ acceptance over the past decade as well as improved processing technologies have offered great opportunities for the development of the specialty soybean industry. The continued expansion of the soy-food industry and sizable increments in the demand of soy-based products has resulted in a growing global demand for food-grade soybeans. There are specific quality attributes which are usually required for specialty soy-food products such as high-protein content, high sucrose content, high water absorption, specific seed size, soft seed texture, and yellow hilum color (Mozzoni, Morawicki, & Chen, 2009; Zhang et al., 2010; Jaureguy, Chen, & Scaboo, 2011). These attributes are largely controlled by genes inherited by the cultivars from their respective parents, which enables breeders to combine unique seed quality and composition traits into elite cultivars, and develop cultivars for specific purposes within the specialty soybean market.

Specialty soybeans are usually grown for particular manufacturers with special premiums, and the manufacturers generally require specific cultivars and on-farm storage. Current equipment and management practices for conventional soybean production can usually be used in the production of value-added specialty soybeans in the U.S. (Kumudini, Grabau, Pfeiffer, & Steele, 2005; Zhang & Kyei-Boahen, 2007). However, with the predominant use of herbicide-tolerant soybeans in commercial production, food-grade soybean production can pose additional challenges and typically requires careful separation from GMO varieties during planting, harvesting, transporting, and storage. In addition, most of the specialty varieties currently available exhibit some relative yield drag compared to elite commodity type cultivars and require a premium to offset the lower yield potential and additional production costs. This causes the need for careful on-farm planning and economic analysis of productivity and profitability. An attempt to capture additional benefits of the increased demand of soy foods will require a multidisciplinary approach. On one hand is the research aspect of...
finding the right cultivars and the adequate technology package for better production. On the other hand, this new technology package has to be economically feasible and, finally, it has to be adopted by growers. In the present study, the production and economic potential of food-grade specialty soybeans were analyzed, and a guideline for cultivar selection and adoption was then established based on economic feasibilities.

2. Materials and Methods

2.1 Break-Even Analysis

Break-even (BE) analysis was used to determine the values at which price, production, output and so on are adequate enough to cover specific costs (Chambers, Herendeen, Joyce, & Penner, 1979; Baute, Sears, & Schaafsma, 2002; Cook et al., 2012). Based on current production and marketing systems, BE analysis was conducted for commodity and specialty soybean cultivars. The minimum yield and price required to match the performance of the top yielding conventional cultivar and transgenic cultivar were determined for three types of specialty soybeans (i.e., small-seeded for natto and soybean sprout; large-seeded for tofu, soymilk, and edamame; and high-protein lines for processing or for export). The basic formula for BE analysis was adapted and solved for the variables of interest.

\[
BE \text{ price} \times \text{ Yield (specialty)} = BE \text{ Revenue} = \text{Total Revenue (commercial)} + \text{Differential cost} \quad (1)
\]

\[
BE \text{ price} = \frac{[\text{Total Revenue (commercial)} + \text{Differential cost}]/\text{Yield (specialty)}}{BE \text{ price} = \text{BE premium} – \text{Commodity price}} \quad (2)
\]

BE Revenue and BE Price are the minimum revenue and price of a specialty soybean that is required to match the profitability of commercial soybean. Total revenue is the product of yield and price. Differential cost is the additional expense incurred for specialty soybean production. Minimum premium price can be obtained by the difference between the BE price and the current commodity price in the market. Minimum premium prices can then be compared with current premiums offered to specialty soybean growers, and used as an indicator for the competitiveness of a particular cultivar.

\[
BE \text{ Y} = \frac{[\text{Total Revenue (commercial)} + \text{Differential cost}]}/\text{Price (specialty)} \quad (3)
\]

BE yield is the minimum yield of specialty soybean required to match the profitability of commercial soybean. BE yield can be compared with commercial soybean cultivar, and also be used as an indicator for the competitiveness of a food-grade specialty soybean cultivar.

2.2 References and Assumptions

Some assumptions and reference statistics were required before conducting the BE and budget analysis. A five-year (2008-2012) average price of $11.57 bu\(^{-1}\) for commercial soybean was obtained from the ‘Quick Stats’ section on National Agricultural Statistics Service website (USDA-NASS, 2013). Three years (2009-2011) average seed costs of $33.70 bu\(^{-1}\) for non-GMO soybean and $51.37 bu\(^{-1}\) for GMO soybean were obtained from ‘2011 Prices Paid’ report on USDA-NASS website.
Price premiums were obtained from Soybean Premiums (http://www.soybeanpremiums.org). Average premiums were around $3.50 bu\(^{-1}\) for small-seeded and $2.50 bu\(^{-1}\) for large-seeded soybeans, and $1.50 bu\(^{-1}\) for high-protein cultivars. A seeding rate of 420,000 seeds ha\(^{-1}\) was the standard for all field plots this rate was also used to calculate seed cost for different sized cultivars. A full-season production system with irrigation was used for the study.

Two scenarios were considered in the BE analysis. Scenario I compared specialty soybeans with a conventional [non-genetically modified organism (GMO)] soybean check. All cost variables were the same except for the seed costs due to different seed sizes and prices. Unit seed cost for specialty soybean was set as 10% higher than conventional non-GMO soybean (Windham & Marshall, 2005). Scenario II compared specialty soybeans with Roundup Ready® (RR) soybean. Since no RR cultivar was planted in this experiment, a computative yield of 46.5 bu ac\(^{-1}\) for RR check was used according to the multiyear data from three different experiments and the yield of conventional check Hutcheson (Table 1). A five year (2003-2007) average price difference of $23.66 ac\(^{-1}\) due to savings in weed management of RR soybeans was obtained from the Arkansas Soybean Research Verification Program (ASRVP) and used as the differential herbicide cost between RR cultivar and specialty soybean test lines. Seed size of the RR cultivar was assumed to be the same as the conventional check, Hutcheson.

Scenario I applies to farmers that would consider switching from conventional non-GMO cultivars to specialty soybean production. Scenario II applies to farmers that would consider switching from a RR system to specialty soybean production.

Table 1. Yields, seed sizes, and seed costs of different types of commodity and specialty soybean cultivars and lines

<table>
<thead>
<tr>
<th>Cultivars/lignes</th>
<th>Yield (Bu/Ac)</th>
<th>Seed Size (Seeds/Lb)</th>
<th>Seed Cost ($/Ac)</th>
<th>Yield Example USDA*</th>
<th>ASRVP</th>
<th>ASPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hutcheson</td>
<td>50.0</td>
<td>3261</td>
<td>33.70</td>
<td>50.6</td>
<td>59.1</td>
<td>61.2</td>
</tr>
<tr>
<td>Roundup Ready®</td>
<td>46.5**</td>
<td>3261</td>
<td>51.37</td>
<td>48.2</td>
<td>53.0</td>
<td>57.9</td>
</tr>
<tr>
<td>Small-Seeded lines</td>
<td>41.1</td>
<td>4650.4</td>
<td>26.71</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>(32.0-52.4)</td>
<td>(4191-5362)</td>
<td>(22.54-28.84)</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Large-Seeded lines</td>
<td>38.6</td>
<td>2254.3</td>
<td>53.87</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>(29.0-48.9)</td>
<td>(2018-2580)</td>
<td>(46.85-59.90)</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>High protein lines</td>
<td>45.4</td>
<td>3898.0</td>
<td>31.52</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>(35.8-55.8)</td>
<td>(3085-4962)</td>
<td>(24.36-39.18)</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

2.3 Field Preparation and Management
The field research was conducted for two years at five locations in Arkansas including: Marianna, Stuttgart, Rohwer, Pine Tree, and Keiser. Planting dates were the second or third week of May. Fertilizer (0-20-20) was applied at 46 kg ha\(^{-1}\) (250 lb ac\(^{-1}\)) and weed management program included
0.7 L (1.5 pt) Treflan and 31 g ha\textsuperscript{-1} (2.8 oz ac\textsuperscript{-1}) Scepter at pre-emergence and 136 g ha\textsuperscript{-1} (12 oz ac\textsuperscript{-1}) Reflex and 68 g ha\textsuperscript{-1} (6 oz ac\textsuperscript{-1}) Fusilade applied at the V1 stage. Irrigation was set at a 2-in water deficit, which resulted in an average of five to eight irrigations per growing season.

Individual plots at each location consisted of four or five rows that were 20-ft (6.1-m) long. Row spacing ranged from 0.48 to 0.96 m by location and the seeding rate for all plots was 429,780 seeds ha\textsuperscript{-1}. Seed yield was determined by harvesting the center two or three rows of each plot at maturity and yield was adjusted to 13% moisture.

Seed size was determined by weighing a random 100-seed sample and was expressed as g 100 seed\textsuperscript{-1}. Three sets of cultivars and experimental lines, targeted for three different types of specialty soybean markets, were used for the economic analysis and included 14 small-seeded cultivars and lines for the natto market, 15 large-seeded cultivars and lines targeted for the tofu and soymilk market, and 21 high-protein lines for the meal market. Plots were arranged in a randomized complete block design with three replications at all locations. The cultivar Hutcheson was used as a conventional check for yield.

2.4 Statistical Analysis
Two-year yields from the five experimental locations were averaged and used in the BE analysis. Linear fit analyses and figure design were conducted using OriginPro 8.0 software (OriginLab, Northampton, MA).

3. Results
3.1 Yield, Seed Size and Seed Cost
The average yield of the conventional check (i.e., Hutcheson) was 20.2 bu ha\textsuperscript{-1} for the five experimental locations, during the two years of this study. Yield drag was observed in both small- and large-seeded test lines when compared with conventional and RR check cultivars. Yields of 14 small-seeded test lines ranged from 64.0% to 92.2% and averaged 80.5% of the yield of the conventional check and ranged from 68.8% to 99.1% with an average of 86.6% of the RR cultivar (Table 1). The yield drag of large-seeded lines was worse than that of small seeded lines. Yields of 15 large-seeded test lines ranged from 58.0% to 97.8% and averaged 77.2% of the yield of the conventional check, and ranged from 62.4% to 105.2% with an average of 83.0% of that of the RR check (Table 1). Better yield performance was observed for high-protein test lines than the small- and large-seeded lines (Table 1). Yields of 21 high-protein test lines ranged from 71.6% to 111.6% with an average of 90.8% of the conventional check, and ranged from 77.0% to 120.0% with an average of 97.6% of the RR check (Table 1). Furthermore, seven of the 21 high-protein lines showed competent or greater yields than the RR check (Fig. 1).

Average seed sizes were 9.8 g 100 seeds\textsuperscript{-1} for small-seeded lines and 20.2 g 100\textsuperscript{-1} seeds for large-seeded lines, which met the seed size criteria for natto and edamame, respectively. Seed sizes of high-protein lines averaged between the conventional check and small-seeded lines. Large seed size...
led to relative lower seed count per pound and resulted in the greatest seed costs of specialty soybeans. On the contrary, small-seed lines had more seed count per pound and had the greatest savings in seed costs. The RR cultivars had the second highest seed cost due to the variety rights of the Monsanto Company. As the result of counteracting between relative smaller seed size and relative higher unit price for specialty soybean seeds, high-protein lines had a similar seed cost to the conventional check (Table 1).

Figure 1. Break-even premium, yield, and expected returns of high-protein specialty soybean under two different planting systems. Scenario I compares specialty soybeans with non-GMO conventional soybean, elite cultivar Hutcheson was used as check. Scenario II compares specialty soybeans with GMO soybean, herbicide resistant RR soybean was used as check. Horizontal dash lines indicate the average premium offered to farmers currently. Vertical dash lines indicate the BE yield at current premium levels. The size of the circles indicates the amount of the expected extra returns or losses.

3.2 BE Analysis of Small-Seeded Lines
Yield data of 14 small-seeded specialty soybeans were used in the BE analysis. Under Scenario I, specialty soybeans were compared with conventional soybean check, Hutcheson. The BE premium required for the 14 small-seeded test lines ranged from $0.85 to $6.36 bu$^{-1}$, with an average of $2.74$ bu$^{-1}$. At the current premium of $3.5$ bu$^{-1}$ for small-seeded soybeans, BE yield needs to be higher than 76.46% of the conventional check’s yield to receive positive returns. The relationship between yield
of specialty soybean as the percentage of the conventional check and the premium required to break-even were shown in the linear equation of Fig. 1a. When the profitable potential was considered, 11 of the 14 test lines could expect extra positive returns ranging from $24.62 to $302.25 ha\(^{-1}\). Four test lines, V00-3657, V96-4181-11, V00-3667 and SS-516, had the potential of offering extra returns of over $247 ha\(^{-1}\) (Fig. 2c).

Under Scenario II, the specialty soybeans were compared with the RR soybean cultivar. The BE premium required for the small-seeded lines ranged from $0.22 to $5.46, with an average of $2.02 bu\(^{-1}\). The BE yield at current premium would be 77.47% of the yield of RR check (Fig. 2b). Most of the test lines (i.e., 12 of 14) could offer positive extra returns which ranged from $19.89 to $151.18 ac\(^{-1}\). Four test lines, V00-3657, V96-4181-11, V00-3667 and SS-516, could offer more than $130 ac\(^{-1}\) in extra returns (Fig. 2d).

**Figure 2.** Break-even premium, yield, and expected returns of small seeded specialty soybean under two different planting systems. Scenario I compares specialty soybeans with non-GMO conventional soybean, elite cultivar Hutcheson was used as check. Scenario II compares specialty soybeans with GMO soybean, herbicide resistant RR soybean was used as check. Horizontal dash lines indicate the average premium offered to farmers currently; Vertical dash lines indicate the BE yield at current premium levels. The size of the circles indicates the amount of the expected extra returns or losses.
3.3 BE Analysis of Large-Seeded Lines

A total of 15 large-seeded cultivar/breeding lines were used in the BE analysis. Under Scenario I, BE premium ranged from $0.71 to $9.19 bu⁻¹, with an average of $4.26 bu⁻¹. To get additional returns at the current premium of $2.5 bu⁻¹ the BE yield should be higher than 85.21% of the conventional check (Fig. 3a). Only three test lines, R01-3234F, R01-3309F, and R01-3685F, with relative higher yield performance could expect positive extra returns. The highest potential extra return was $87.6 ac⁻¹ (Fig. 3c).

Under Scenario II, BE premium ranged from $0.95 to $9.59, with an average of $4.57 bu⁻¹. At the current premium of $2.50 bu⁻¹, the BE yield needs to be at least 92.92% of the RR check to break-even (Fig. 3b). Only two test lines, R01-3234F and R01-3309F, could expect positive extra returns of $75.89 and $0.65 ac⁻¹, respectively (Fig. 3d).

**Figure 3.** Break-even premium, yield, and expected returns of large seeded specialty soybean under two different planting systems. Scenario I compares specialty soybeans with non-GMO conventional soybean, elite cultivar Hutcheson was used as check. Scenario II compares specialty soybeans with GMO soybean, herbicide resistant RR soybean was used as check. Horizontal dash lines indicate the average premium offered to farmers currently. Vertical dashed lines indicate the BE yield at current premium levels. The size of the circles indicates the amount of the expected extra returns or losses.
3.4 BE Analysis of High-Protein Lines

More gentle slopes were observed in the linear fit analysis for the 21 high-protein lines tested, compared to the small- and large-seeded soybean lines (Fig. 3a & 3b). Under Scenario I, BE premiums ranged from $-1.26 to $4.35, with an average of $1.30 bu⁻¹ (Fig. 1a). Negative BE premiums indicated that the high-protein lines did not require a premium to meet desired returns. Considering the current premium of $1.50 bu⁻¹, BE yield needs to be higher than 89.3% of the conventional check (Fig. 1a). Approximately two-thirds (14 of 21) of the test lines could bring extra returns with the greatest potential extra return of $153.75 ac⁻¹ (Fig. 3c).

Under Scenario II, BE premiums ranged from $-1.77 to $3.54 bu⁻¹, with an average of $0.66 bu⁻¹. At the current premium of $1.50 bu⁻¹, BE yield needs to be at least 90.71% of the RR check (Fig. 1b). At current premium level 17 of the 21 lines would provide potential positive extra returns, with the greatest extra profit of $182.57 ac⁻¹ (Fig. 1d).

4. Discussion

Food-grade specialty soybeans usually have yield performances below that of the conventional or Roundup Ready soybeans (Jaureguy et al., 2011; Kumudini et al., 2005). However, in this study, the average yield of each test group only accounted for 77.2 to 90.8 % of the conventional check (e.g., Hutcheson) yield. Large-seeded soybeans exhibited poor yield performance when compared to the others in this study. Yield drag for some specialty soybeans can be attributed to the large seed sizes and, for others, the negative correlation between seed yield and protein concentration (Medic, Atkinson, & Hurburgh, 2014; Eren, Kocatürk, Hosgün, & Azcan, 2012). The differential pricing mechanism for high-protein (Farris, Crowder, Dahl, & Thompson, 1988) and other food-grade soybeans should be reconsidered to encourage the production and breeding of the specialty soybeans that will be economically competitive with commodity soybean cultivars and production.

Based on the BE analysis and considering the challenges to meet industry requirements and agronomic standards, there is an allowable yield drag with no profit penalty, assuming premiums stay at current levels. Higher production costs need to be offset with higher yields and adequate premium prices for a profitable operation. At the time of our analysis with available premiums, specialty soybean production could be a profitable operation for the United States if climate-adapted high-yielding cultivars are made available. Considering both the higher profitability potential and lower risk chance, planting high-protein specialty soybean will be a profitable option for farmers under the current premium conditions. As another option, small-seeded soybean lines could also be a profitable crop for interested farmers. Production of large-seeded soybeans may be risky, unless a high-yielding cultivar is used, or a much higher premium will be offered to the farmers.

In 2004, the American Soybean Association in Japan reported that the U.S. supplied 51.5% of soybean used for tofu and 77% for natto consumption in Japan and there are still opportunities for market growth. Thus, increased breeding efforts for specialty soybean production would help soybean producers capture additional profits through the specialty markets.
Our results demonstrated that specialty soybean adoption could provide additional income to growers that would consider specialty soybean production. Likewise, BE analysis revealed potential profit losses if yields and premiums are below the critical thresholds. Average BE premiums were $2.74, $4.26, and $1.30 bu⁻¹ under Scenario I, and $2.02, $4.57, and $0.66 bu⁻¹ under Scenario II for small seeded, large seeded, and high-protein test lines, respectively. At current premium level of $3.50 bu⁻¹ for small seeded, $2.50 bu⁻¹ for large seeded, and $1.50 bu⁻¹ for high-protein specialty soybean, BE yields for these three types of specialty soybean should be 76.46, 85.21, and 89.28% of the check’s yield when compared with conventional soybean; and 77.47, 92.92, and 90.71% of the check’s yield when compared with Roundup Ready soybean, respectively. Careful cultivar selection and testing in the local environments and production systems are needed if farmers are to consider the adoption of specialty soybeans at current market conditions. Also, as commodity prices fluctuate, additional break-even analyses must be conducted to accurately estimate future profitability of specialty soybeans production. Additionally, contractors should consider the performance of desirable cultivars and the potential premium offers in the contracted area where the specialty crops will be produced. Adequate testing will ensure optimal yields for the growers and desired soybean quality for the processors.

References


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