Published December 28, 2016

Decision Support Software for Soybean Growers: Analyzing Maturity Group and Planting Date Tradeoffs for the US Midsouth

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Abstract

Among other choices, soybean [*Glycine max* (L.) Merr.] producers in the Midsouthern United States face decisions regarding the optimum maturity group (MG) to select for a given planting date and location. From a profitability perspective, weather-driven irrigation water needs and harvest date implications on seasonal sale price complicate planting choices. Using a large set of experimental trials conducted across 10 locations in the Midsouth, the DSSAT-CROPGRO-Soybean crop simulation model was validated. Thereafter, the model was used to create a database of simulated 30-year yield and irrigation water needs based on past weather data for 13 locations. With that data, a spreadsheet-based tool was developed to compare soybean planting strategies by selecting from 2 soil textures, 14 different planting weeks, and 8 relative maturity group (rMG) choices ranging from rMG 3.0 to 3.4 to rMG 6.5 to 6.9 in 0.5-rMG intervals at each location. User-specific comparisons allow insights on yield potential, yield risk, phenology, irrigation needs, soybean price, and irrigation cost sensitivity analysis as well as profitability assessment across MGs and planting dates.

Justification

Many studies have evaluated the yield response of irrigated soybean to planting date among different MGs. A comprehensive experiment that considers these responses over a number of years is beyond the scope and capabilities of most agricultural research programs. Therefore, using a validated model for generating simulated agronomic soybean performance data, a tool was developed to aid producers when making planting choices using a point and click, online tool featuring both agronomic and economic output.

Decision tools that perform complex data analysis but require only minimal input are powerful tools for helping producers make more informed decisions for optimizing soybean yield and producer net returns. As an example, Iowa State University has their Soybean Planting Decision tool available for online users to predict yield outcomes across MG and planting date using 11 locations across

Management Guides

Core Ideas

- Modifying maturity group and planting date in soybean affects yield potential, yield risk, phenology, soybean price, and irrigation needs.
- Choosing among a set of 14 planting dates and 8 relative maturity groups is complex.
- Decision support software can help compare between relative maturity groups.

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Received 4 Apr. 2016.
Accepted 15 Sept. 2016.

Abbreviations: MG, maturity group; rMG, relative maturity group.

Conversions: For unit conversions relevant to this article, see Table A.

Published in Crop Forage Turfgrass Manage. Volume 2. doi:10.2134/cftm2016.04.0028

Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
67.19	60-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha
102.8	acre-inch	meter^3, m^3
3.78	gallon, gal	liter, L (10^{-3} m^3)
0.304	foot, ft	meter, m
36.74	$/60-lb bu	$/Mg

Minnesota, Iowa, and Missouri (Archontoulis, 2015). Such tools are useful as they provide easily accessible information to producers, whereas information provided in scientific journal articles is often not targeted for the practitioner or those making producer recommendations. Our intent was to introduce a decision-support tool for practitioners called SOYMAP, which is a Microsoft Excel–based spreadsheet tool that provides agronomic and economic information for making **SOY**bean **M**aturity **A**nd **P**lanting date decisions.

Model Data Background

For this analysis, data from a regional planting date and MG study (Salmerón et al., 2014, 2015, 2016) were used to develop a user-friendly decision tool that can help producers select an optimum MG choice for their location and expected planting date. Both yield and irrigation cost differences between MG choices are considered in determining the optimum MG for a given planting date and location together with user-selected soybean price seasonality and user-specified production cost information.

Data collected from 10 locations in the Midsouth, 4 planting dates, and 16 soybean cultivars from MG 3 to 6 were used to calibrate (2 years) and validate (1 year) the DSSAT-CROPGRO-Soybean crop simulation model (Jones et al., 2003; Hoogenboom et al., 2012) for accurate predictions of soybean phenology (first date of flowering, seed fill, and maturity), yield, and irrigation needs. Thereafter, simulations with 30 years of historical weather data for (i) a range of latitudes from 30°27′ N (Baton Rouge, LA) to 38°57′ N (Columbia, MO) in the US Midsouth; (ii) two soil textures (clay and silt loam); (iii) planting dates in weekly intervals from mid-March to late June; and (iv) MG from 3 to 6 in 0.5-rMG intervals were used to generate model predictions for that range of planting dates, latitude, and MG combinations. Altogether, there were a total of 2912 scenarios predicted for each of the 30 years. Estimates of profitability relevant for comparing among MG choices were calculated for each situation based on expected seasonal sale price and irrigation needs. The crop simulations using this historical weather data allowed calculation of likelihoods of covering total production costs.

Results such as probabilities of achieving yields above a certain level, risks of low yields, or comparison of likelihoods of covering production costs among different MG choices can be valuable information for producers when deciding which MG to plant at a given location and planting date. The producer need only enter the location closest to their operation, a choice of two soils (clay or silt loam) to estimate irrigation needs, the two rMG they wish to compare, cost of irrigation per acre-inch, and a price expectation for the harvest year in question. A choice of default values or input ranges is provided where possible. Economic sensitivity analysis to "what-if" questions related to sale price and irrigation cost allow quick comparison across rMG. Risk analyses provide probabilistic estimates for attaining certain yield levels as well as economic net returns suitable for determining optimum rMG subject to the user's risk preferences. The tool works on an Excel platform.

The objective of this paper is to illustrate how producers can gain easily accessible information they need to make a MG choice for a given planting date, soil texture, and location. This report provides a step-by-step description of how to use the tool along with brief interpretations of the output.

Installation And Troubleshooting

SOYMAP is designed for full-screen mode and will work with Excel 2010 and later versions. It is best to download the file from http://agribusiness.uark.edu/decision-support-software.php and save it to a convenient location on the user's hard drive for later access. This spreadsheet contains macros that the user needs to enable by responding to prompts. Since the tool works in full-screen mode it hides the toolbar etc. It restores to Excel default settings when the user exits the program using the "Stop & Save" icon (Fig. 1 [7]) or the X near the top right of the screen. The user is encouraged to save and close other spreadsheets prior to using SOYMAP and not to resize the screen. A first step to troubleshooting is to close and restart the program from the latest saved version.

Description of Input and Output of SOYMAP

Location

The first input screen is designed to allow the user to specify a location to analyze (Fig. 1 [1]). Locations are provided in

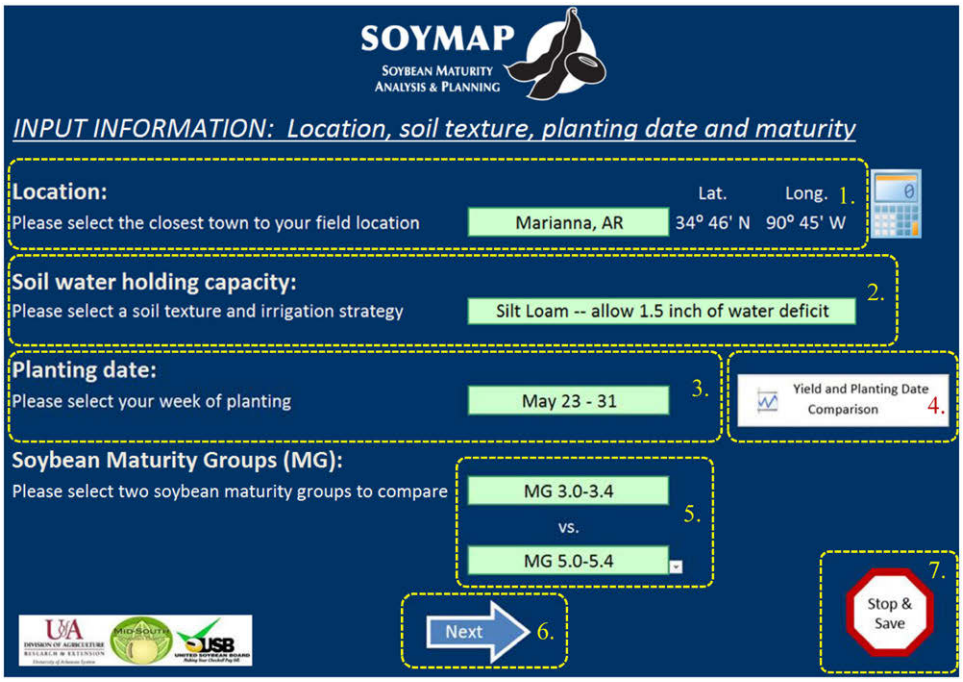


Fig. 1. Location, soil texture, planting week, and soybean maturity group selection input screen.

a drop-down menu starting with the northernmost location (Columbia, MO) at the top of the list and ending with the southernmost location (Baton Rouge, LA). The drop-down menu is activated by left-clicking on the location indicator.

Soil Texture

With the location chosen, the user selects from a choice of two soil textures in a drop-down menu. The soil texture affects the soil water holding characteristics and hence the estimated irrigation amounts (Fig. 1 [2]).

Planting Date

With location and soil texture chosen, the user can now choose from planting dates as early as 15 to 22 March to as late as 23 to 30 June (Fig. 1 [3]). The white button for "Yield and Planting Date Comparison" (Fig. 1 [4]) to the right calls up another screen (Fig. 2) that provides information about yield and irrigation requirements across all planting date choices. It also shows a comparison of yield potential across the two MG choices that were selected in Fig. 1. Choosing the "Yield and Planting Date Comparison" button begins a computer database search for appropriate information. This process takes about 15 sec or longer depending on the computer processing speed. The user may choose "OK" to proceed or "Cancel" to return to the first screen (Fig. 1) to select MGs to compare. If "OK" is selected, a screen similar to Fig. 2 is displayed for the selected location and MG choices.

After selecting the "Yield and Planting Date Comparison," the user should close the message box (Fig. 2 [1]) that may

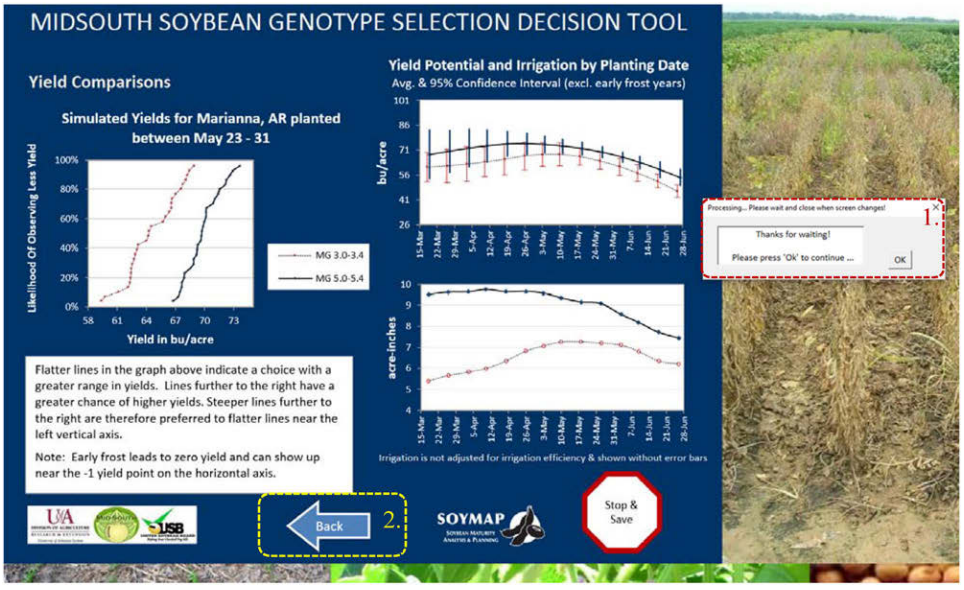


Fig. 2. Yield cumulative distribution functions, yield potential, and soil water deficit by planting date. MG, maturity group.

appear anywhere on the computer screen. The top-right graph in Fig. 2 shows the yield potential for the selected MGs along with error bars for each planting week as simulated over 30 years of historical weather data. The error bars show the estimated range of yields obtainable with a 95% confidence interval. The graph is provided to allow the user to evaluate their planting date and MG selection from a perspective of yield potential.

The bottom right graph in Fig. 2 shows the estimated amount of irrigation water needs that are *not* adjusted for irrigation efficiency (this will be discussed later). In Fig. 2, the later maturing soybean with a longer production season requires more irrigation as expected, and there is a noticeable drop in irrigation needs when delaying planting to late May for MG 5.0 to 5.4. Error bars are not shown as they are quite large and would obscure the information in the graph.

The graphs on the right in Fig. 2 provide an overview of yield potential and irrigation requirements over the entire planting window for the selected MG choices and location. The "Back" button (Fig. 2 [2]) allows the user to modify MGs and planting date by repeating the above steps. Detailed information about a set of two MG choices and planting week, as specified by the user, is displayed on the left side in Fig. 2. The example in Fig. 2 shows yields of MG 3.0 to 3.4 vs. MG 5.0 to 5.4 at Marianna, AR, planted between 23 May and 31 May. The simulated yields over the 30-year weather history are plotted from least to highest and assigned a probability or likelihood of attaining at least that yield which has implications for risk and yield potential (Schlaifer, 1959). A steeper line indicates less risk or more consistent yields over time, and a line that lies to the right shows greater yield. If the user specifies a northern location and selects among the earliest planting week choices, there is a chance of frost killing the stand, resulting in zero yield which is displayed in this graph as a yield of −1 bu/acre (not shown).

Maturity Group

Appropriate MGs can be selected (Fig. 1 [5]) using the drop-down menus (ranging from MG 3.0–3.4 to MG 6.5–6.9). With MGs for comparison selected, the user proceeds to the screen illustrated in Fig. 3 by pushing the "Next" button near the bottom center of the screen (Fig. 1 [6]) to gain access to additional information about MG comparisons.

Again, a "Processing…Please wait" message box appears and after waiting approximately 5 sec, the user is informed about the likelihood of a killing frost after planting and information about yields and yield risk using box plots and an associated table containing the information (Fig. 3). The risk of freezing near the top center of the page (0% in this case) is shown as a horizontal red bar when this risk exists. Information in the table is highlighted in a light shade of green when a MG choice is superior to the other (Fig. 3 [1]). "Min." and "Max." refer to probabilities of yields reaching at least specific values, and they are near zero and 100%, respectively. The box plot to the right in Fig. 3 shows the 25th and 75th percentile of yields in the middle box as well as the range of simulated yields (excluding frost years) with the error bars. The information shown in Fig. 3 is thus complementary to that shown in the "Yield and Planting Date Comparison" (Fig. 2).

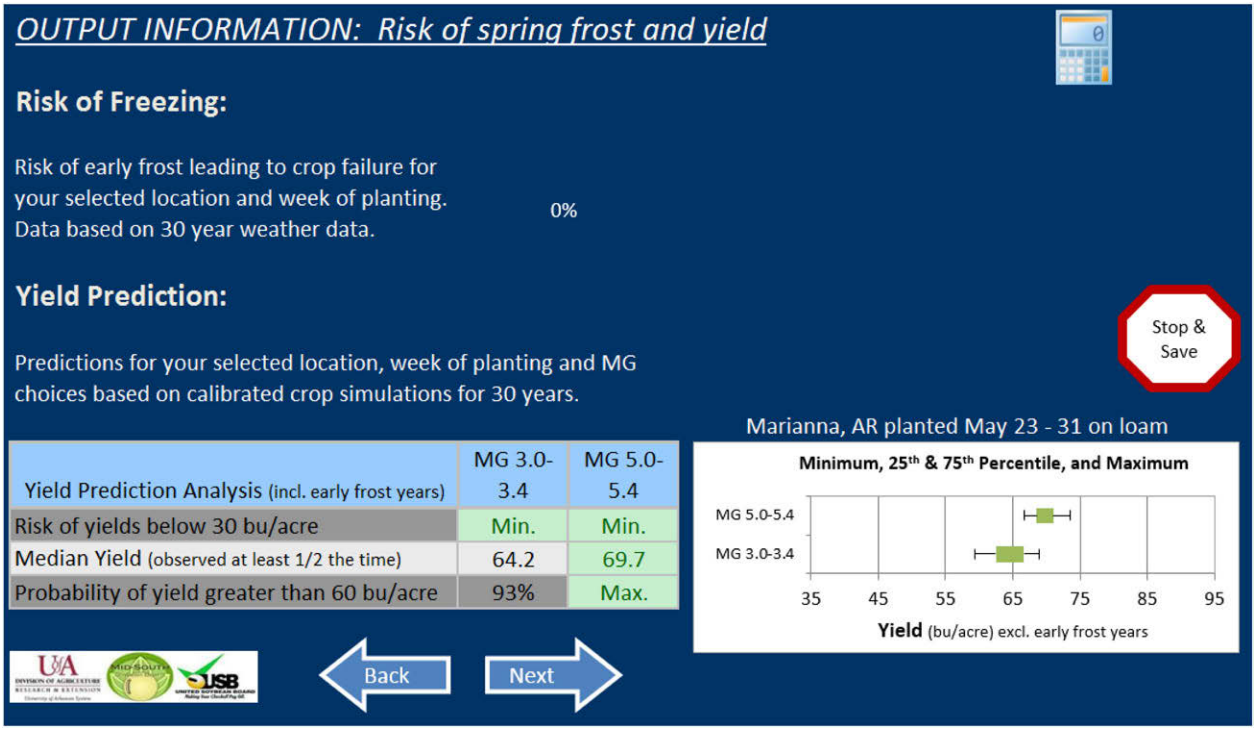


Fig. 3. Risk of early-season crop killing frost and yield distribution description. MG, maturity group.

Choosing the "Back" button in Fig. 3 allows the user to return to the input screen—to modify the inputs—or to continue with the selections made using the "Next" button. The latter choice advances the user to information about phenological differences between chosen MGs that are location-, planting week–, and soil texture–specific (Fig. 4). Information is presented about the first date of flowering (R1), the onset of seed fill (R5), and when harvest maturity (R8) is anticipated.

From the phenology screen (Fig. 4), the user may proceed to the "Irrigation" screen (Fig. 5). The screen highlights irrigation requirements along with 95% confidence intervals in both graphical and tabular format. Text provides an explanation that irrigation requirements are the amounts of irrigation needed by the crop, ignoring irrigation efficiency of application. Irrigation requirements, therefore, reflect the amount of water the plant will need over the growing season less that water stored in the soil at planting and the amount received as rainfall given location-specific, historical weather patterns, and the selected soil texture.

Economic Analyses

The first economic analysis screen shown in Fig. 6 allows the user to tailor economic analyses to their operation by choosing:

1. Irrigation costs pertinent to their operation (depth of well, energy type, energy cost, and irrigation type as shown in Fig. 6 [1]). Estimated cost per acre-inch is calculated based on inputs (Fig. 6 [2]) or the user can specify their own estimate (Fig. 6 [3]). A link to a calculator (Fig. 6 [4]) is provided by pressing the calculator icon and is available on nearly every screen. Note that the cost estimate is adjusted for irrigation efficiency, which is set to 50% for furrow–flood irrigation and 75% for center pivot irrigation (Hogan et al., 2007). Insights about calculations are available by moving the cursor to the red triangles located near the top-right corner (Fig. 6 [2]), for example.

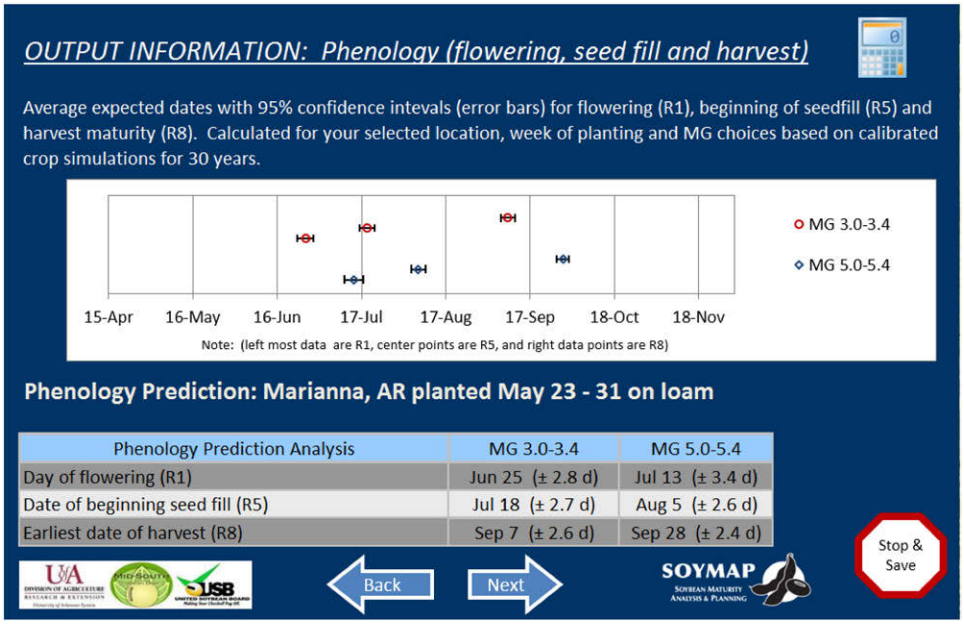


Fig. 4. Phenology information screen. MG, maturity group.

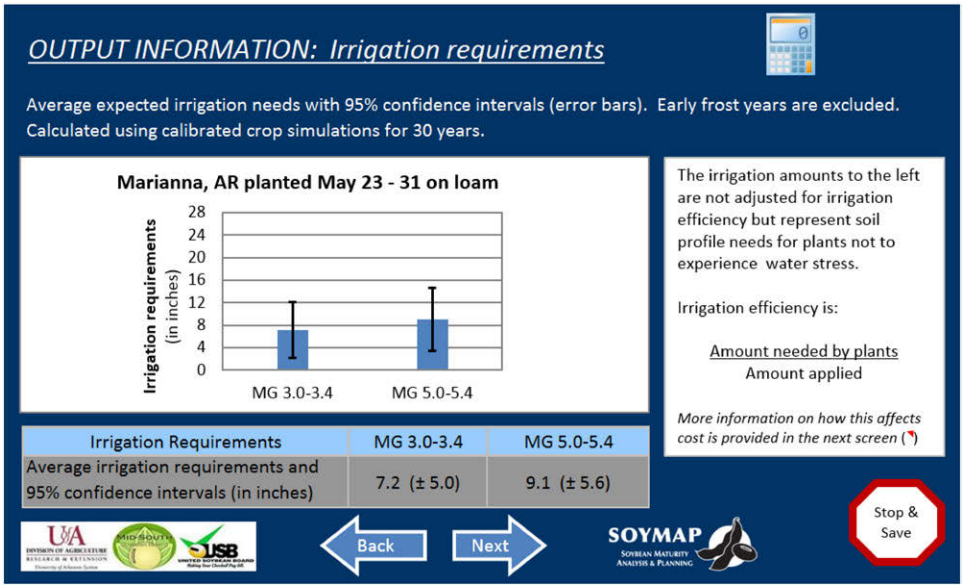


Fig. 5. Soil water deficit screen. MG, maturity group.

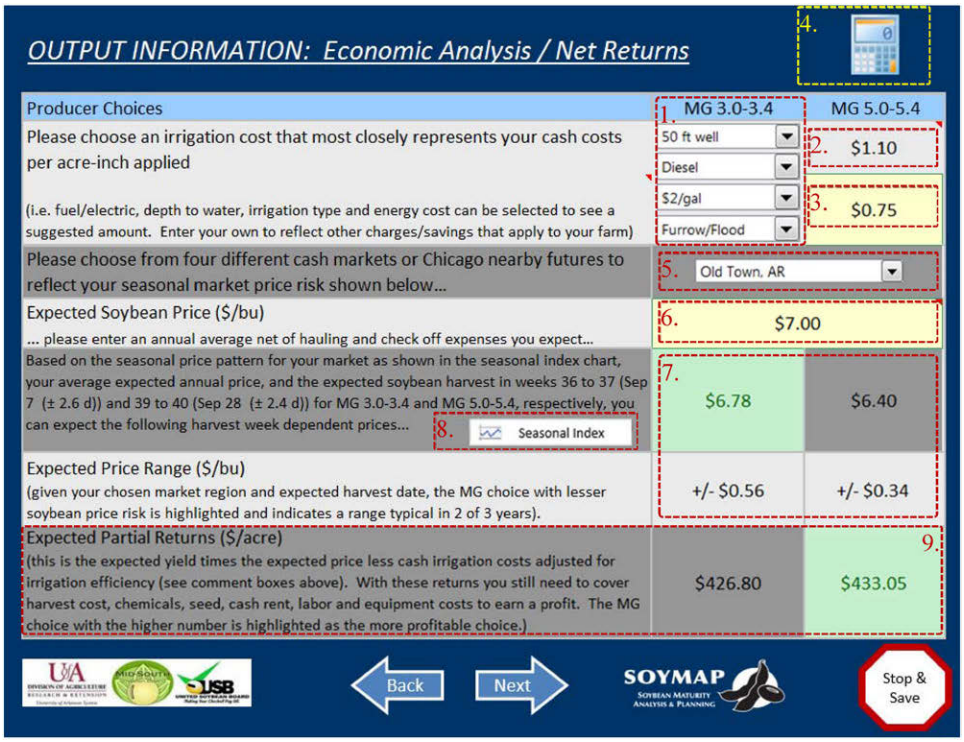


Fig. 6. Economic analysis of irrigation cost, seasonal sale price, and partial returns. MG, maturity group.

2. The user can choose among several key soybean markets (Fig. 6 [5]) for which historical price data of No. 2 Soybean were available (USDA AMS, 2015). Drop-down menu choices include cash prices for Joplin, MO, New Orleans, LA, Memphis, TN, Old Town, AR, Kansas City, MO, and Chicago Futures prices to tailor expected seasonal sale price changes, relative to an annual expected sale price, to the user's location of production. The user provides the annual expected soybean sale price (Fig. 6 [6]) and the computer adjusts the cash sale price expectation (Fig. 6 [7]) along with sale price range associated with MG choices (shown in the top line of the table) on the basis of expected harvest date and market chosen. The MG's expected sale price that is highest in comparison with the other MG choice is again highlighted. Pressing the "Seasonal Index" button (Fig. 6 [8]) provides a graphical summary of changes in a weekly soybean price index for Old Town, AR (Fig. 7), for the entire year or the harvest window by toggling the check box in Fig. 7 (1).

Seasonal index values, the ratios of a harvest week's soybean price to the 52-week centered moving average price, as averaged over 2005 to 2014, are plotted along with their 95% confidence interval. A seasonal index value above 1 implies a price premium compared with the annual price, whereas a seasonal index value <1 is indicative of a price discount. Multiplying a MG's seasonal index value (Fig. 7 [2 or 3]) with the annual expected sale price (Fig. 6 [6]) leads to the cash sale price expectation for each MG (Fig. 6 [7]) (Goodwin, 1994). The error bars are used to develop the corresponding price ranges. In that sense, the length of the error bars represents price risk that can vary by the market chosen as well as the anticipated harvest week given MG-specific harvest maturity. The seasonal index graph can therefore help with the choice of planting week and MG choice as early-maturing MG and early planting may lead to a seasonal sale price premium at greater or lesser price risk when compared with late planting of a later-maturing MG soybean, again, depending on the market chosen. Choosing the "Back" button returns the user to the first economic analysis screen (Fig. 6).

3. Partial returns are defined as the expected yield times the expected seasonally adjusted sale price less irrigation costs per acre (Fig. 6 [9]) and are used to compare the relative profitability between MG choices (Duffy et al., 2015). The MG choice with higher partial returns is again highlighted. Irrigation costs are adjusted for irrigation efficiency which, in turn, depends on irrigation type.

4. From the "Economic Analysis/Net Returns" screen (Fig. 6), the user may proceed to a second economic output screen focused on "Sensitivity and Risk" analyses (Fig. 8). The sensitivity analysis provides "what-if" scenarios. As an example, the analysis reveals how much the MG 3.0–3.4 sale price would have to change to offset yield and irrigation cost differences when compared with MG 5.0–5.4 at its current price. Alternatively, holding the expected sale prices constant, the irrigation cost sensitivity analysis answers how much irrigation cost per acre-inch have to change to offset yield and irrigation cost differences between MG choices.

5. Risk analyses different from yield and price risk, discussed previously, center around providing

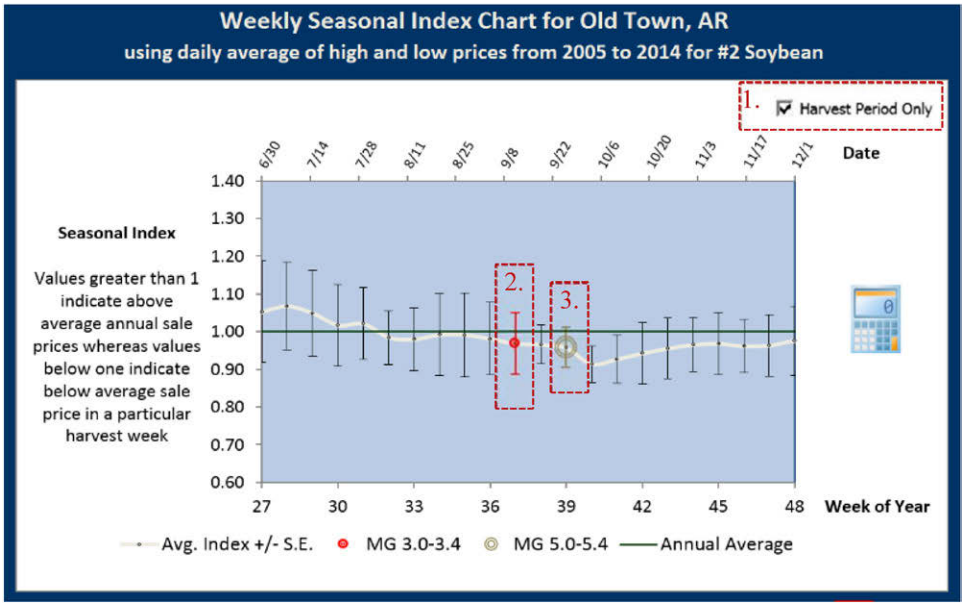


Fig. 7. Ten-year average and standard deviation of seasonal index for Old Town, AR. MG, maturity group.

estimates of probabilities of meeting profitability thresholds. In addition to irrigation costs already specified in Fig. 6, the user specifies other production costs (e.g., seed, fertilizer, chemicals, fuel, labor, equipment, and rent or land charges) to reflect total production costs incurred to grow an acre of soybean (Fig. 8 [1]). The likelihood of breaking even or making money is answered in the second row of the risk analysis section (Fig. 8 [2]) with a higher likelihood of breakeven between MG choices again highlighted with a light green tint. This analysis is subject to the level of other production expenses entered. A user may, for example, specify higher costs to determine the likelihood of meeting such a higher profitability threshold, which now includes expenses and perhaps a profit margin. By the same token, capital costs for equipment and land may be ignored to determine the likelihood of covering cash costs only. This context is important as profitability estimates including these other production expenses are used in subsequent economic output screens.

The bottom row of the risk analysis section in Fig. 8 makes annual comparisons of producer-specified net returns (sales – total specified expenses). The MG 5.0 to 5.4, in this case, have higher net returns than MG 3.0 to 3.4 nearly every year as the probability is 97%. Pushing the "Other Comparisons" button (Fig. 8 [3]) leads to an output screen which summarizes the economic analysis in graphical form (Fig. 9).

The summary table near the top right in Fig. 9 outlines key differences between the selected MG choices and also provides an estimate of producer-specified net returns per acre-inch of irrigation used. In contrast to Fig. 2 and 5, where irrigation information is not adjusted for irrigation efficiency, the irrigation information in Fig. 9 is presented after adjusting for irrigation efficiency. The graph on the left presents yield risk as previously described for the "Yield and Planting Date Comparison" screen in Fig. 2. Note that yields are shown on

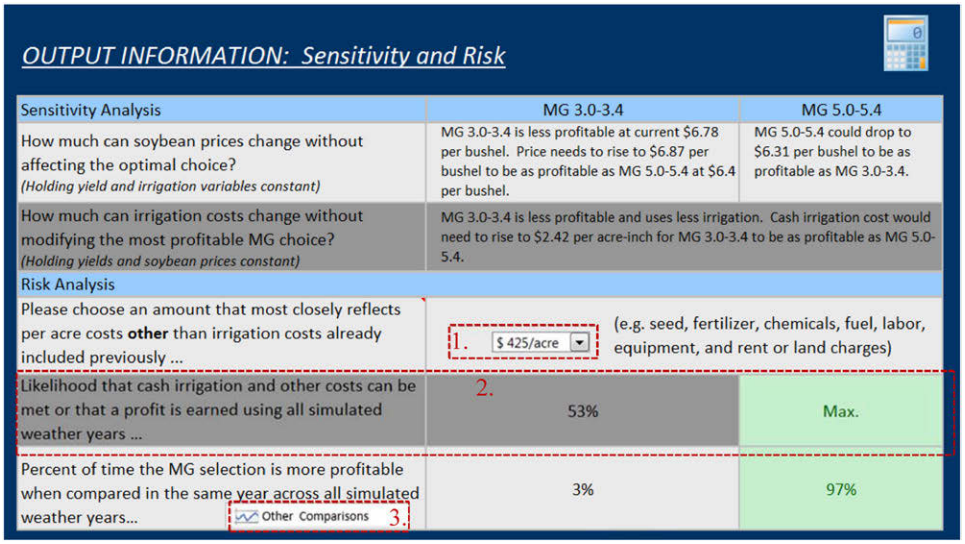


Fig. 8. Other production cost, likelihood of breakeven, and annual net return comparisons. MG, maturity group.

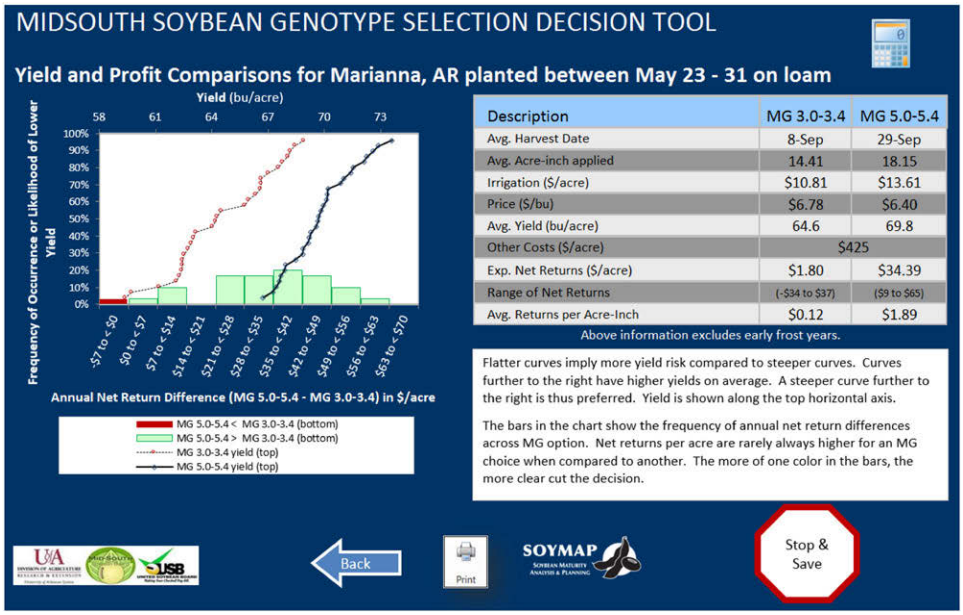
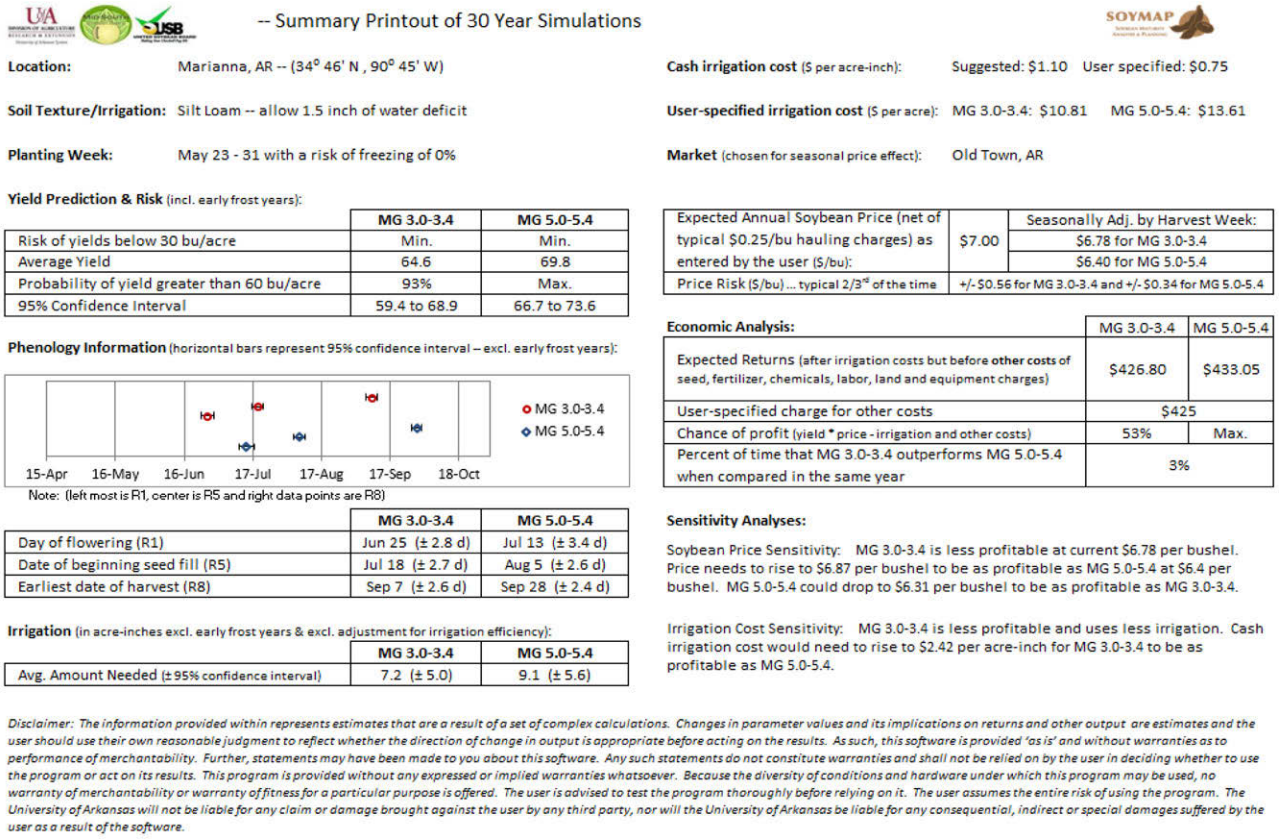


Fig. 9. Economic summary output. MG, maturity group.

the top horizontal axis with the likelihood of achieving at least that level of yield on the left vertical axis. The bar chart on the bottom represents a frequency distribution of annual profitability differences among MG choices. As explained in the white text box near the bottom right, the more one-sided the color regime, the clearer the choice. In this case, the MG 5.0–5.4 choice is more profitable than the MG 3.0–3.4 choice most of the time (97%).

The "Print" button (Fig. 9) near the bottom allows the user to print a summary of the analysis presented on this page. A similar "Print" button on the previous page allows the user to print a summary of all key statistics relevant for making an informed MG by planting date decision on a single page as shown in Fig. 10.



-- Summary Printout of 30 Year Simulations

Location: Marianna, AR -- (34° 46' N , 90° 45' W)

Soil Texture/Irrigation: Silt Loam -- allow 1.5 inch of water deficit

Planting Week: May 23 - 31 with a risk of freezing of 0%

Yield Prediction & Risk (incl. early frost years):

	MG 3.0-3.4	MG 5.0-5.4
Risk of yields below 30 bu/acre	Min.	Min.
Average Yield	64.6	69.8
Probability of yield greater than 60 bu/acre	93%	Max.
95% Confidence Interval	59.4 to 68.9	66.7 to 73.6

Phenology Information (horizontal bars represent 95% confidence interval -- excl. early frost years):

Note: (left most is R1, center is R5 and right data points are R8)

	MG 3.0-3.4	MG 5.0-5.4
Day of flowering (R1)	Jun 25 (± 2.8 d)	Jul 13 (± 3.4 d)
Date of beginning seed fill (R5)	Jul 18 (± 2.7 d)	Aug 5 (± 2.6 d)
Earliest date of harvest (R8)	Sep 7 (± 2.6 d)	Sep 28 (± 2.4 d)

Irrigation (in acre-inches excl. early frost years & excl. adjustment for irrigation efficiency):

	MG 3.0-3.4	MG 5.0-5.4
Avg. Amount Needed (± 95% confidence interval)	7.2 (± 5.0)	9.1 (± 5.6)

Cash irrigation cost ($ per acre-inch): Suggested: $1.10 User specified: $0.75

User-specified irrigation cost ($ per acre): MG 3.0-3.4: $10.81 MG 5.0-5.4: $13.61

Market (chosen for seasonal price effect): Old Town, AR

Expected Annual Soybean Price (net of typical $0.25/bu hauling charges) as entered by the user ($/bu):	$7.00	Seasonally Adj. by Harvest Week: $6.78 for MG 3.0-3.4; $6.40 for MG 5.0-5.4
Price Risk ($/bu) ... typical 2/3rds of the time		+/- $0.56 for MG 3.0-3.4 and +/- $0.34 for MG 5.0-5.4

Economic Analysis:

	MG 3.0-3.4	MG 5.0-5.4
Expected Returns (after irrigation costs but before other costs of seed, fertilizer, chemicals, labor, land and equipment charges)	$426.80	$433.05
User-specified charge for other costs	$425	
Chance of profit (yield * price - irrigation and other costs)	53%	Max.
Percent of time that MG 3.0-3.4 outperforms MG 5.0-5.4 when compared in the same year	3%	

Sensitivity Analyses:

Soybean Price Sensitivity: MG 3.0-3.4 is less profitable at current $6.78 per bushel. Price needs to rise to $6.87 per bushel to be as profitable as MG 5.0-5.4 at $6.4 per bushel. MG 5.0-5.4 could drop to $6.31 per bushel to be as profitable as MG 3.0-3.4.

Irrigation Cost Sensitivity: MG 3.0-3.4 is less profitable and uses less irrigation. Cash irrigation cost would need to rise to $2.42 per acre-inch for MG 3.0-3.4 to be as profitable as MG 5.0-5.4.

Disclaimer: The information provided within represents estimates that are a result of a set of complex calculations. Changes in parameter values and its implications on returns and other output are estimates and the user should use their own reasonable judgment to reflect whether the direction of change in output is appropriate before acting on the results. As such, this software is provided 'as is' and without warranties as to performance of merchantability. Further, statements may have been made to you about this software. Any such statements do not constitute warranties and shall not be relied on by the user in deciding whether to use the program or act on its results. This program is provided without any expressed or implied warranties whatsoever. Because the diversity of conditions and hardware under which this program may be used, no warranty of merchantability or warranty of fitness for a particular purpose is offered. The user is advised to test the program thoroughly before relying on it. The user assumes the entire risk of using the program. The University of Arkansas will not be liable for any claim or damage brought against the user by any third party, nor will the University of Arkansas be liable for any consequential, indirect or special damages suffered by the user as a result of the software.

Fig. 10. Print summary. MG, maturity group.

Summary

A new soybean maturity group and planting date analysis tool called SOYMAP is available at http://agribusiness.uark.edu/decision-support-software.php. The tool uses a database of DSSAT-CROPGRO simulation output for a number of locations, planting dates, and MG choices. SOYMAP adds user-friendly access with a minimum of data input required by the user for the interpretation of >87,000 simulations to allow users to compare MG and planting date combinations specific to soil texture at 13 locations across the Midsouth. SOYMAP provides agronomic and economic information that will be valuable for producers as they consider various irrigated soybean management approaches to manage aspects of yield, irrigation, profitability, and risk.

Acknowledgments

The authors gratefully acknowledge partial support for this research from the United Soybean Board and the US Midsouth Soybean Board.

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