User Manual

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Table of Contents

Introduction 1
Installation, Entry and Exit Instructions 1
Stop & Save 2
Resize the screen 2
First Input Screen (Location, Soil Texture, Planting date and Maturity Group Selection) 2
Location 2
Drop down menu 2
Soil Texture 2
Planting Date 2
Yield and irrigation water needs across all planting date choices. 2
Yield and Planting Date Comparison 2
Yield potential for the selected MGs 3
Error bars 3
Estimated amount of irrigation water needs 3
'Back' button 3
Likelihood of attaining at least that yield 4
Chance of frost 4
Maturity Group: 4
'Next' button 4
Light shade of green 5
Min. and Max. 5
Box plot 5
Irrigation efficiency 6
Economic analysis 6
Irrigation costs 6
Calculator 6
Red triangles 6
Market information 6
Annual expected sale price 6
Cash sale price expectation 6
Seasonal Index 6
Harvest period only 7
Price range 7

Price risk 7
Seasonal premium or discount 7
Partial Returns 7
Sensitivity Analyses 8
Risk Analyses 8
Other production costs 8
Breakeven 8
Other Comparisons 9
Irrigation applied 9
Frequency distribution of annual net return differences 9
Print 9
Predictive accuracy 9
Summary Printout: 10
Technical Appendix 11

NOTE: Numbers in parentheses in the text are references to callout boxes in the Figures.

***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.*

USER MANUAL

Introduction

Decision tools that perform complex data analysis but require only minimal input from producers are powerful tools for making more informed decisions that help to maximize yield and net returns. Data from a regional planting date and MG study was used to develop a user friendly decision tool that can aid producers by selecting optimum MG choices for their location and expected planting date.

Data collected from 8 locations in the Midsouth, 4 planting dates, 16 soybean cultivars from maturity groups (MG) 3 to 6, were used to calibrate and validate the DSSAT-CropGro-Soybean crop simulation model for accurate predictions of soybean phenology (first date of flowering, seed fill and maturity), yield and irrigation water needs. Thereafter, simulations with 30 years of historical weather data for a range of latitudes in the US Midsouth, planting dates in weekly intervals from mid-March to late-June, and MG from 3 to 6 in 0.5 rMG (relative maturity group) intervals were used to generate model predictions for that range of planting dates, latitude and MG combinations. Relative returns were calculated for each situation based on expected seasonal sale price and irrigation needs. Using this historical information 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 what MG to plant at a given location and planting date. The producer need only enter the latitude of their location, a choice of two soil conditions to estimate irrigation needs, the two rMG they wish to compare, cost of irrigation per acre-inch and a price expectation for the expected harvest date. 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 returns suitable for determining optimum rMG subject to the user's risk preferences. The tool will work on an Excel platform.

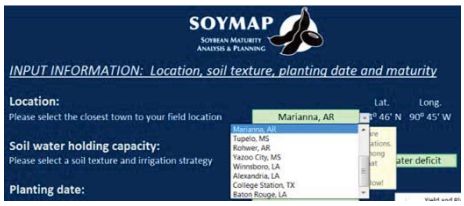
The following paragraphs provide information about how to install the program and how to modify inputs to get the desired output for questions you may have.

Installation, Entry and Exit Instructions

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 in a convenient location on your hard drive so that you will find its location later. This spreadsheet contains macros and so you may get messages from your machine to enable the macros.

Since the tool works in full-screen mode it hides the tool bar etc. It restores to Excel default settings when you exit the program. ***It is best to close all other spreadsheets you may have open*** and then open SOYMAP. It is also best to exit the program using the '***Stop & Save***' logo located near the bottom right of each screen. You will be prompted whether you want to save changes or not. You can also exit using the ✕ near the top right. If you cancel closing the spreadsheet you will be prompted to press cancel a second time. This is necessary to restore defaults properly. Should you push the 'Save' or 'Don't Save' buttons with the second request to cancel and experience a strange exit, simply reopen the spreadsheet and exit without saving. ***Also, please do not resize the screen as the program is designed to work in full screen mode. You can always exit the program, saving the changes made, and restart the program from the folder where you saved the program***.

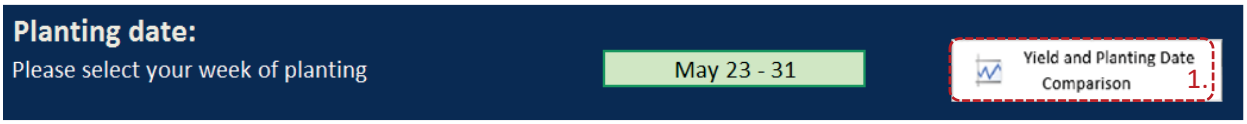
First Input Screen (Location, Soil Texture, Planting date and Maturity Group Selection)



Location: The first input screen is designed to allow you to specify which of several locations is closest to your operation. Locations are provided in a drop down menu starting with the northern most location, Columbia, MO at the top of the list and ends with the most southern location of Baton Rouge, LA. ***The drop down menu is activated by clicking once with the left mouse button on the green location box with Marianna, AR*** selected as the default location on the downloaded version of the program.

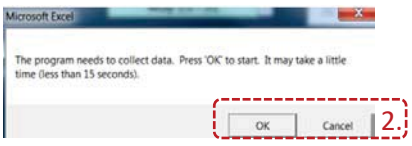
Soil Texture: Once you have selected the location, you can choose between two soil textures with different soil water holding capacities that affect the amount of estimated irrigation needed. Again, the drop down menu activates when left-clicking the mouse with the pointer on the green shaded cell.

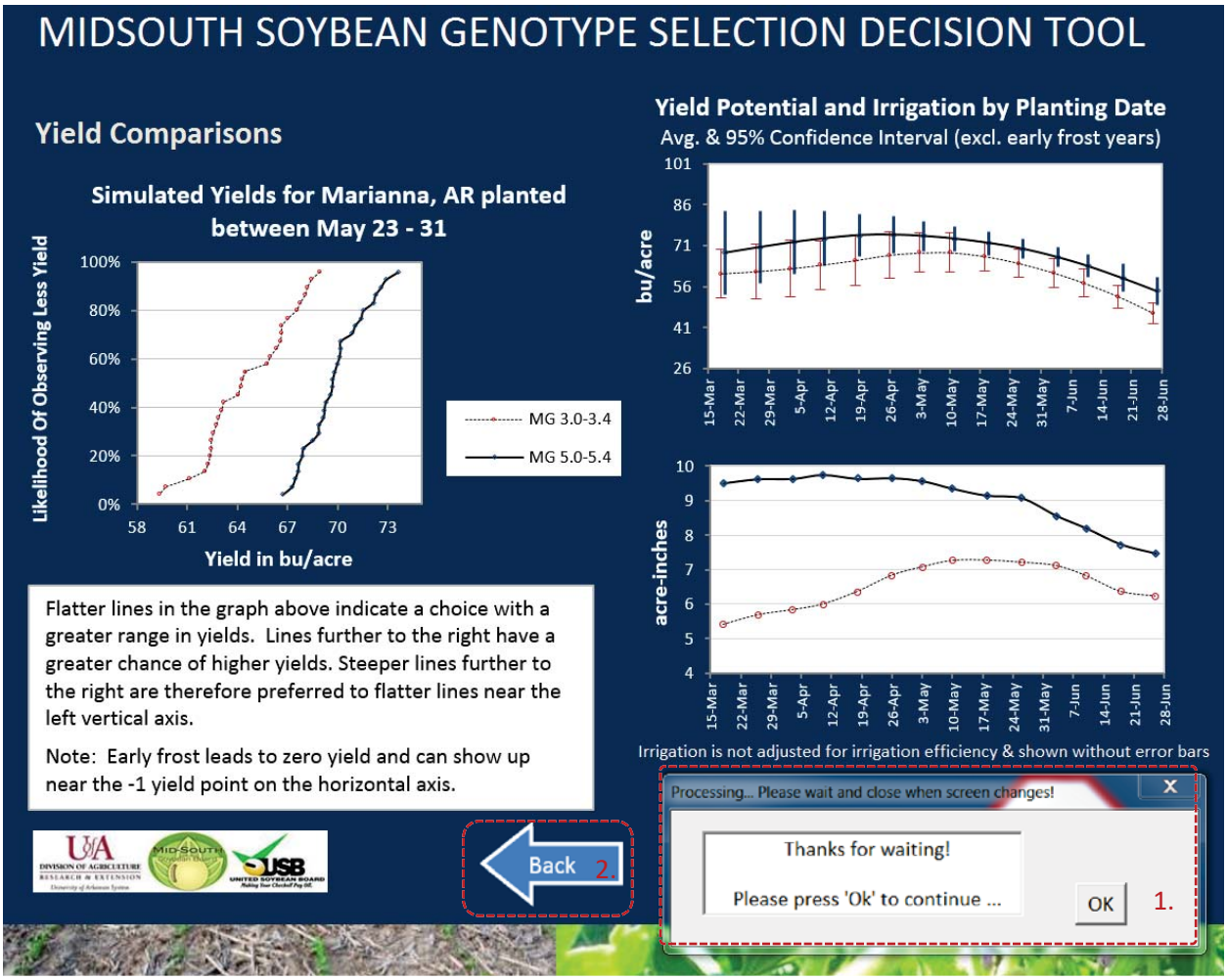
Planting Date: With location and soil texture chosen, you can now pick the planting date. A drop down window allows choosing a planting week as early as March 15-22 and as late as June 23 – 30. You can use the scroll bar near the right of the drop down menu and move the scroll bar while holding the left mouse button and moving the mouse.



To the right of the planting week selection is a button (1) that calls up another screen (shown next page) to provide information about ***yield and irrigation water needs across all planting date choices.***

It also shows a comparison of yield potential across two MG that are selected on the existing screen. Pushing the '***Yield and Planting Date Comparison***' button begins a computer database search for appropriate information. This process takes about 15 seconds or longer depending on the processing speed of your computer. Choose 'OK' (2) to proceed or you can press 'Cancel' (2) to return to the first input screen and select MGs to compare. If you press 'OK' you will get the following screen assuming you have not changed the location away from Marianna, AR and you are comparing 3.0-3.4 vs. 5.0-5.4 as your MG choices.





The first thing to do is to close the message box (1) which may appear anywhere on the computer screen by clicking on the 'OK' button as instructed. The top right graph 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 statistical likelihood of 95% of the time. In the graph shown MG 3.0-3.4 are estimated to show lower yield potential than the later maturing MG 5.0-5.4 when planted at Marianna, AR regardless of planting date.

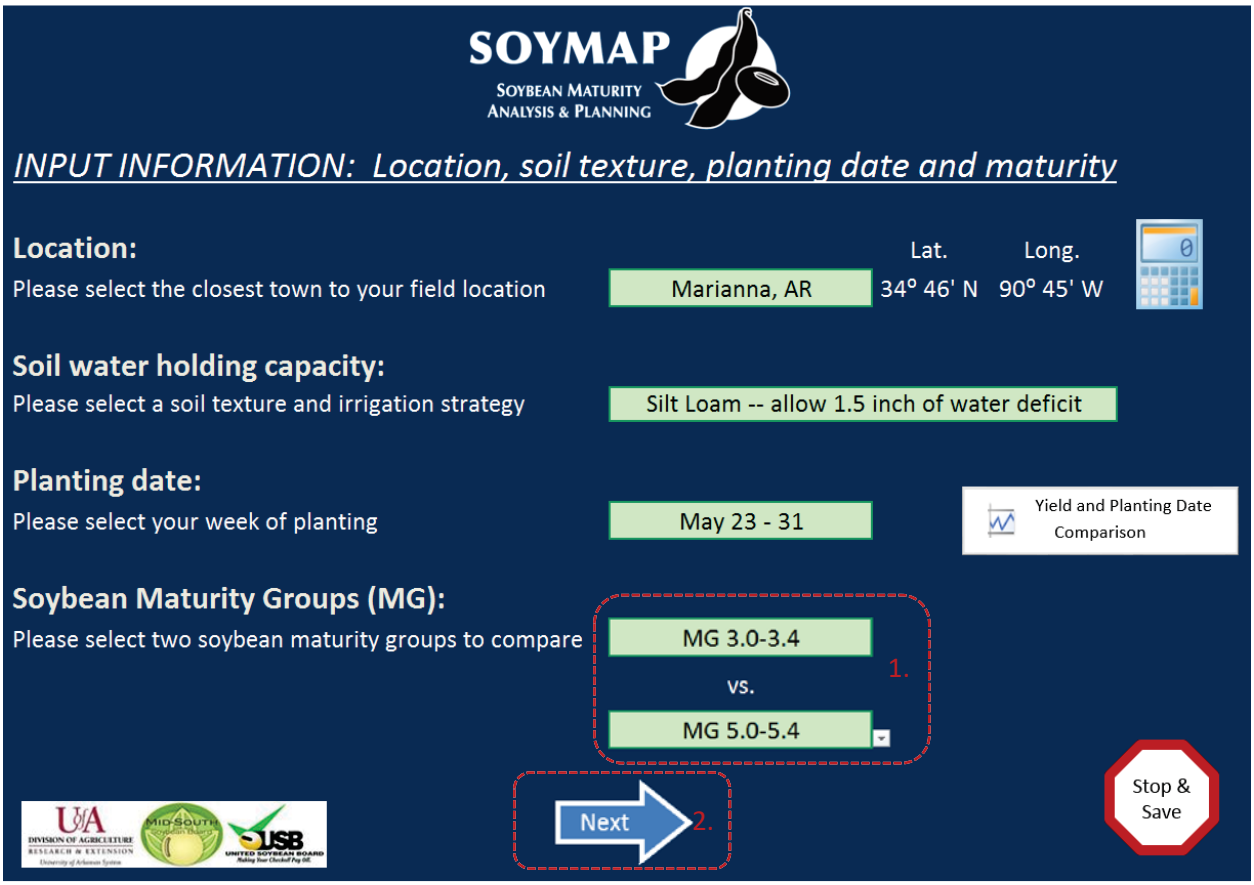
The bottom right graph shows the ***estimated amount of irrigation water needs*** that are *not* adjusted for irrigation efficiency (this will be discussed later). In this case, the later maturing soybean with a longer production season requires more irrigation as expected and there is a noticeable drop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

The graphs on the right are helpful to select a planting week for comparing MG choices at the indicated location. Pushing the ***'Back' button*** (2) near the bottom center allows you to return to the first input screen and pick different MGs and planting week to get detailed yield information provided in the left hand side graph as shown at the top of this page.

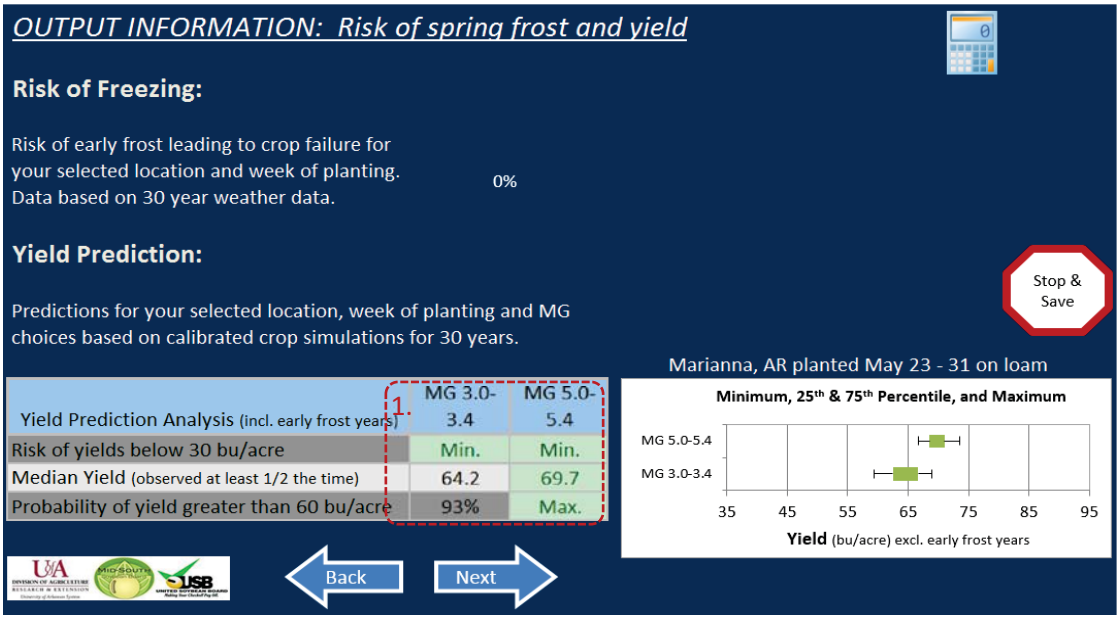
The left hand side graph shows yields of MG 3.0-3.4 vs. MG 6.5-6.9 at Marianna, AR, planted between May 23rd and May 31st as this was the location, planting week and MG comparison selected in the first input screen. As indicated in the text box below the graph, plotting the simulated yields over the 30 year weather history from smallest to largest and assigning a probability or ***likelihood of attaining at least that yield*** has implications for risk and yield potential. Most producers prefer a steeper line (less risk) and a line that lies to the right (more 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 which leads to zero yield and shows up on this plot as a yield of -1 bu/acre (not in this case).

After having viewed the information on the 'Yield and Planting Date Comparison' output screen shown at the top of the previous page, the user may want to change the MGs to compare as well as the planting date. This is accomplished by pushing the 'Back' button and returns the user to the first input screen. ***The user can move back and forth as many times as they like. Moving to the 'Yield and Planting Date Comparison' page takes 15 seconds, going 'Back' is nearly instantaneous. This is because the computer needs to look up information and update the graphs each time the user changes location, planting week or MG.***

Maturity Group: Appropriate MGs can be selected (1) using the drop down menus (ranging from MG 3.0-3.4 to MG 6.5-6.9) as shown below and with a similar process as described for planting date, soil texture and location above. Once MGs are selected, perhaps after several iterations of looking at the 'Yield and Planting Date Comparison' screen, the user can push the ***'Next' button*** (2) near the bottom center of the screen to gain access to additional information about MG comparisons at any of the available locations, MG comparisons and planting weeks. This manual uses the choice below.



Pushing the 'Next' button, by now with the familiar 'Processing…Please wait' message box, the user is informed about the likelihood of a stand killing frost after planting and information about yields and yield risk using box plots and an associated table containing the information (as shown at the top of the next page). Using the yield estimates derived by running a crop growth simulation model with historical weather for the last 30 years, the user can see the ***risk of freezing*** near the top center of the page (0% in this case but shown as a horizontal red bar when this risk exists).



The table at the left has information highlighted in a ***light shade of green*** when a MG choice is superior to the other (1). ***Min. and Max.*** refer to probabilities near zero and 100%, respectively. In the above case, risks of yield dropping below 30 bu/acre is minimal as the simulation model runs showed no yield observations below that yield level. A review of the box plot to the right shows the 25th and 75th percentile of yields in the middle box as well as the minimum and maximum yields (excl. frost years) with the capped thin lines. With all estimated yields greater than 65 bu/acre (as shown by the left end of the ***box plot*** for MG 5.0-5.4), the probability of greater than 60 bu/acre yield is shown as 'Max.' in the table on the left for MG 5.0-5.4, whereas that likelihood is smaller at 93% for MG 3.0-3.4 when compared to the MG 5.0-5.4. The information shown above thus tells a similar story to the graph shown in the 'Yield and Planting Date Comparison' screen shown on p.3 above.

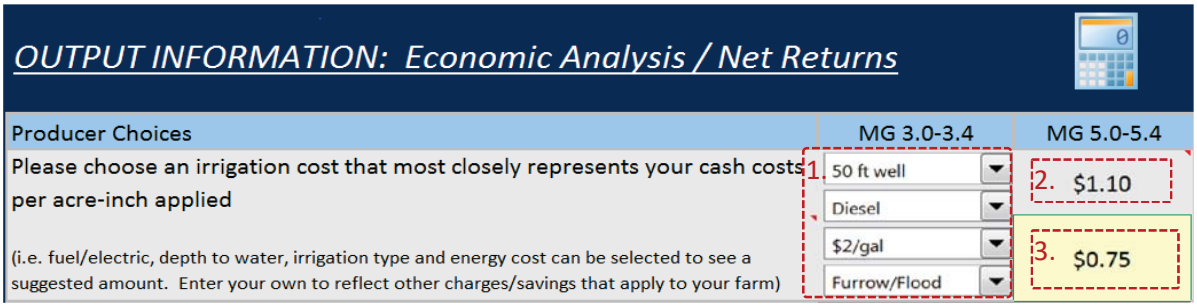
Pushing the 'Back' button allows the user to again return to the input screen -- perhaps to modify MG and planting week, and/or soil texture. The 'Next' button advances the user to the next output screen informing the user about phenological differences between chosen MG that are location-, planting week-, and soil texture-specific.

This information is presented to allow the producer to make harvest scheduling decisions (R8), provides information about the first date of flowering (R1) when poor pollinating conditions are typically not desirable and the onset of seed fill (R5) when attention to irrigation is critical. The information is provided in both tabular and graphical format but is not shown as a figure in this manual. The by now familiar 'Next' and 'Back' buttons work as expected. 'Back' returns to the previous 'Yield and Risk of Frost' screen and 'Next' moves to the 'Irrigation' screen. The screen highlights needed irrigation

requirements along with 95% confidence intervals. Next to the graph is a text box that describes how ***irrigation efficiency*** is handled by the program. Typically, sprinkler irrigation is more efficient than flood or furrow irrigation. Irrigation needed reflects the amount of soil-stored water the plant will need over the growing season given location-specific, historical weather patterns and the selected soil texture. The information is also presented in tabular form. This screen is not shown here as it is self-explanatory.

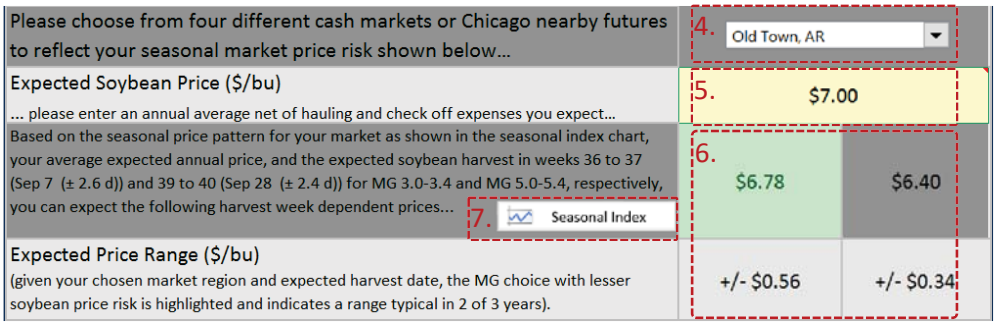
The 'Next' button moves the user to another output screen that allows the user to tailor their *economic analysis* to their operation by allowing the user to choose:

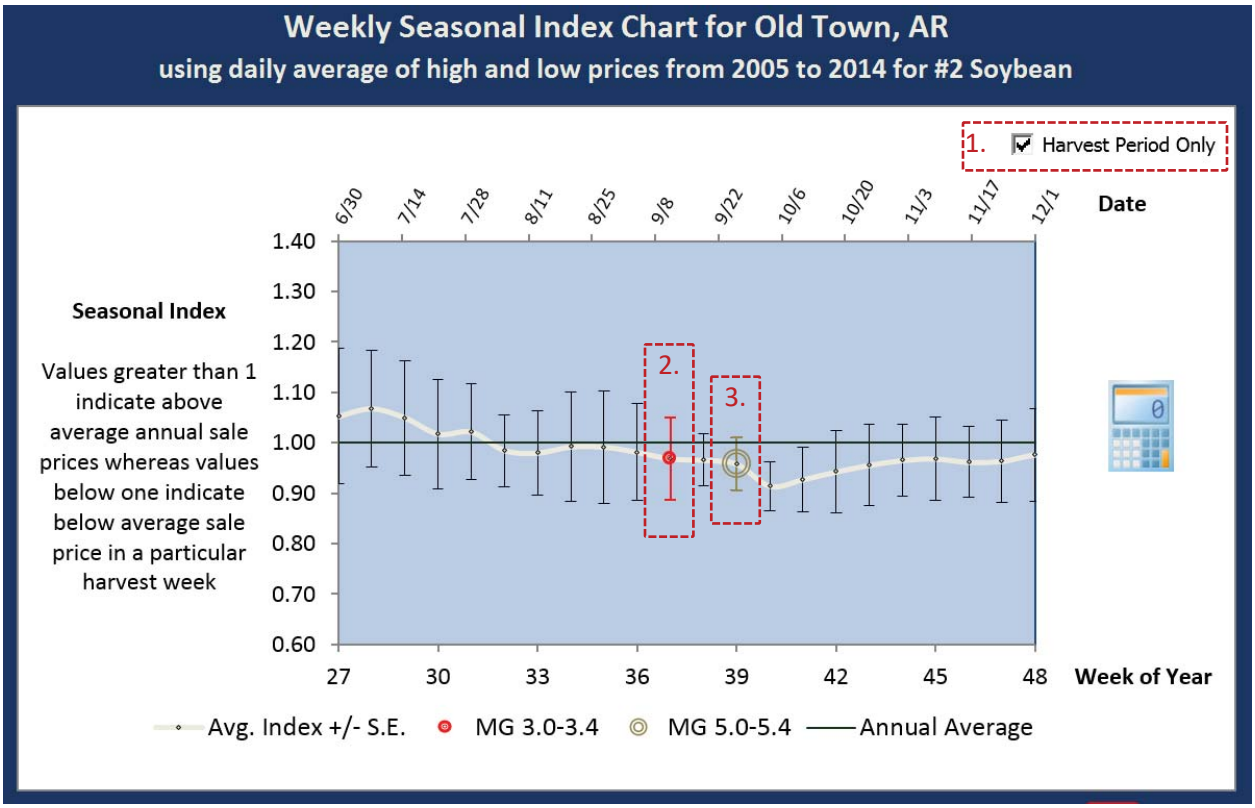
i) ***Irrigation costs*** pertinent to their operation (depth of well, energy type, energy cost, and irrigation type) which can be selected using the drop down menu activated by left-clicking on the downward arrow at the right side of the menu items (1). The computer calculates cost per acre-inch (2) and the user can specify their own estimate (3). A link to a ***calculator*** is provided by pressing the calculator



logo 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. Insights about calculations are available by moving the cursor to the ***red triangles*** located near the top right corner of (2), for example.

ii) ***Market information*** can also be tailored to the operation. The user can choose among several key soybean markets (4) for which historical price data of #2 Soybean were available. Drop down menu choices include Joplin, MO, New Orleans, LA, Memphis, TN, Old Town, AR, Kansas City, MO and Chicago Futures. This choice is made available to tailor expected seasonal sale price changes, relative to an ***annual expected sale price***, to the location of production. The user provides his or her annual expected soybean sale price (5) and the computer adjusts the ***cash sale price expectation*** (6) 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 most appropriate market location 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 (7) provides a graphical summary of how weekly soybean prices change relative to the annual soybean sale price in the context of the most recent 10 year (2005-2014) average of weekly soybean prices for the market location chosen (see top of next page).





The user can specify whether they want to see the whole year or the ***harvest period only*** (1) by toggling the check box. The point estimate on the fat white line for each harvest week (with associated date shown near the top of the graph), represents an index value. The index value times the ***annual expected sale price*** ((5) on the previous page) leads to the ***cash sale price expectation*** ((6) on the previous page). The tail ends of the vertical lines for each sale week (2), as shown for the earlier maturing MG 3.0-3.4 in the graph above, shows that approximately two thirds of the time, the seasonal index for that harvest week will lie between approximately 0.88 and 1.06 with an average near 0.97 such that the sale price expectation and ***price range*** is slightly below the expected annual sale price ((5) on previous page) with a range of +/- 9% of the average ***cash sale price expectation*** ((6) on previous page). The later maturing MG 5.0-5.4, on the other hand receives a slightly larger seasonal price discount as its average seasonal index value is near 0.96 with a slightly smaller price range as the vertical error bar (3) is shorter than the one for the MG 3.0-3.4 choice. In that sense, the error bars represent ***price risk*** on the basis of seasonal cash harvest price subject to the market chosen. A shorter bar means less price risk whereas a longer bar means more price risk. The position relative to the horizontal line relays whether there is a ***seasonal premium or discount*** relative to the annual sale price. Planting earlier, in this location and trying to harvest in week 28, for example, is expected to lead to a relatively risky seasonal price premium that may or may not be large enough to offset potential yield penalties or difficulties with coordinating field operating activities with other crops on the farm than planting mid to late May as chosen in this case. Pushing the 'Back' button allows the user to return to the economic analysis screen.

iii) ***Partial Returns*** are defined as the expected yield times the expected seasonally adjusted sale price less irrigation costs per acre. Irrigation costs are adjusted for irrigation efficiency which, in turn, depends on irrigation type. The name, *partial* returns, reflects that only part of production costs are

accounted for. The MG with the highest partial return is highlighted to represent the superior choice from a partial return perspective (information not shown in the manual). Pushing the 'Next' button leads to a second economic analysis screen.

iv) ***Sensitivity Analyses*** for soybean price and irrigation costs are shown to provide a 'what-if' analysis. If the MG 5.0-5.4 expected sale price is held constant, how much would the MG 3.0-3.4 sale price have to change to offset yield and irrigation cost differences? Or, holding the expected sale prices constant, how much would irrigation cost per acre inch have to change to offset yield and irrigation cost differences?

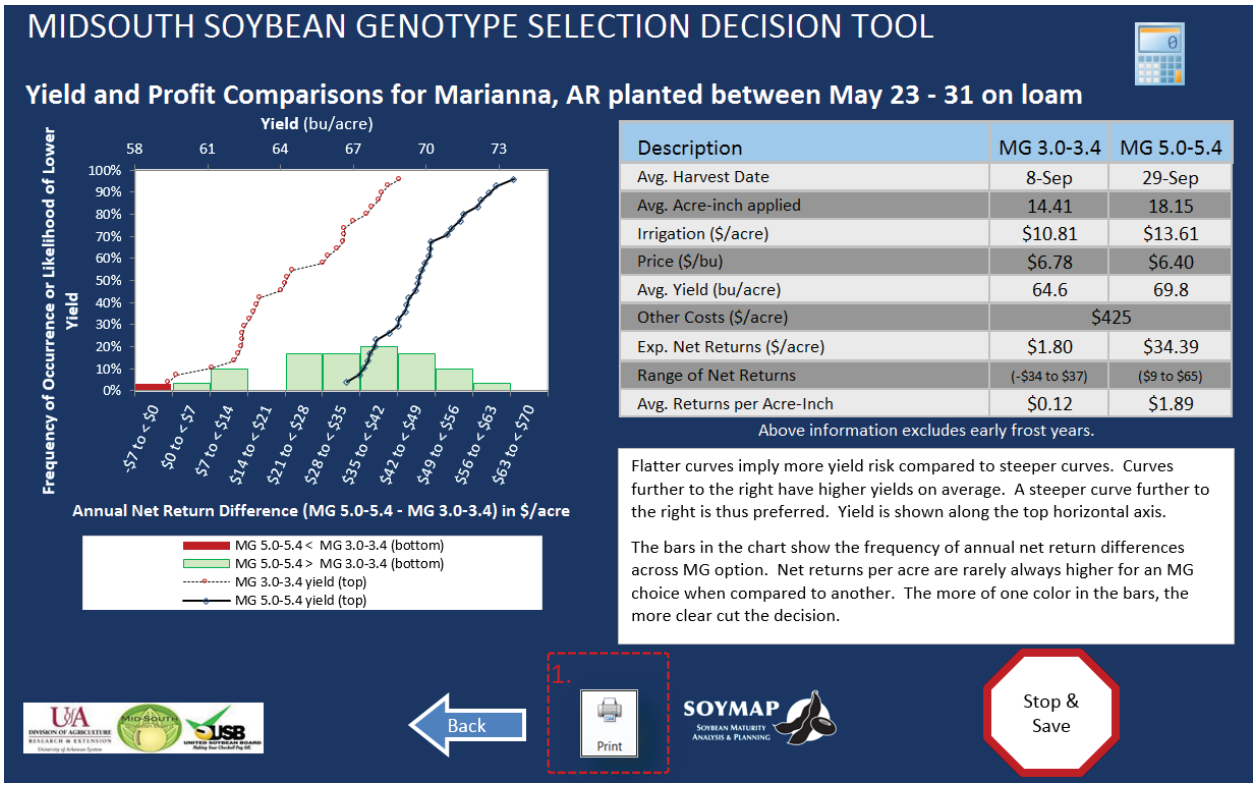
Sensitivity Analysis	MG 3.0-3.4	MG 5.0-5.4
How much can soybean prices change without affecting the optimal choice? *(Holding yield and irrigation variables constant)*	MG 3.0-3.4 is less profitable at current $6.78 per bushel. Price needs to rise to $6.87 per bushel to be as profitable as MG 5.0-5.4 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.
How much can irrigation costs change without modifying the most profitable MG choice? *(Holding yields and soybean prices constant)*	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.	

v) ***Risk Analyses*** different from yield and price risk, already discussed, center around providing estimates of probabilities of meeting return thresholds. To accomplish this, the user must specify ***other production costs*** to reflect total production costs incurred to grow an acre of soybean. These ***other production costs*** represent seed, fertilizer, chemicals, fuel, labor, equipment, rent and/or land charges that are incurred regardless of what MG is chosen and are in addition to the cash irrigation expenses already estimated previously. On the basis of simulated historical yields given historical weather, the cash sale price expectation and the other production costs (1), what is the likelihood of breaking even or making money or covering the other production expenses (1) specified by the user? This question is answered in the second row of the risk analysis section (2) with a higher ***likelihood of breakeven*** between MG choices again highlighted with a light green tint. Remember that this 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 threshold which now includes expenses and perhaps a profit margin. By the same token, they may not enter capital costs for equipment and land to determine likelihood of covering cash costs only. This context is important.

Risk Analysis		
Please choose an amount that most closely reflects per acre costs **other** than irrigation costs already included previously …	1. $ 425/acre (e.g. seed, fertilizer, chemicals, fuel, labor, equipment, and rent or land charges)	
2. Likelihood that cash irrigation and other costs can be met or that a profit is earned using all simulated weather years …	53%	Max.
Percent of time the MG selection is more profitable when compared in the same year across all simulated weather years… 3. Other Comparisons	3%	97%

The bottom row of the risk analysis section (as shown near the bottom of the previous page) makes annual comparisons of producer-specified net returns (sales – specified expenses). MG 5.0-5.4, in this case, have higher returns than MG 3.0-3.4 nearly every year as the probability is 97%. Pushing

the '***Other Comparisons***' button ((3) on the previous page) leads to the following output screen which summarizes the economic analysis in graphical form.



The summary table near the top right outlines key differences across MG choice and also provides an estimate of producer-specified net returns per acre-inch of water used. In contrast to a previous screen where irrigation information is not adjusted for irrigation efficiency, the ***irrigation applied*** 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. Note that yields are shown on 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 net return differences*** among MG choices. As explained in the white text box near the bottom right, the more one-sided the color regime, the more clear the choice. In this case, MG 5.0-5.4 net returns exceed those of MG 3.0-3.4 most of the time (97%).

The ***Print*** button (1) near the bottom allows the user to print out the summary of the analysis presented on this page. A similar ***print*** button on the previous page allows the user to print out a summary of all key statistics relevant for making an informed MG by planting date decision on a single page as shown on the next page of this user manual.

A technical appendix follows in the last pages of this manual to showcase the ***predictive accuracy*** of simulation runs when compared to actual yields observed across several locations and planting dates for several MG.

Summary Printout:

-- 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%

Cash irrigation cost ($ per acre-inch): Suggested: $

User-specified irrigation cost ($ per acre): MG 3.0-3.4:

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

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

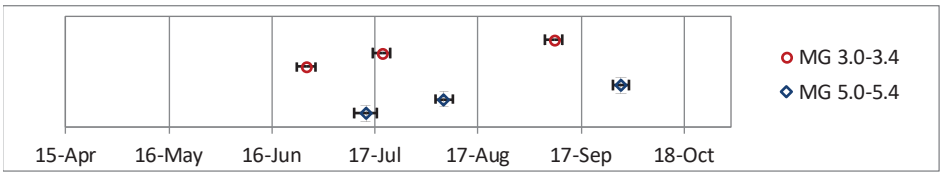
	MG 3.0-3.4	MG 5.0-5.4
Risk of yields below 30 bu/acre	Min.	Min.
Average Yield	64.6	69.8
Probability of yield greater than 60 bu/acre	93%	Max.
95% Confidence Interval	59.4 to 68.9	66.7 to 73.6

Expected Annual Soybean Price (net of typical $0.25/bu hauling charges) as entered by the user ($/bu):	$7.00	
Price Risk ($/bu) ... typical 2/3rd of the time		+/- $0.56 f

Economic Analysis:

Expected Returns (after irrigation costs but before **other cost** fertilizer, chemicals, labor, land and equipment charges)
User-specified charge for other costs
Chance of profit (yield * price - irrigation and other costs)
Percent of time that MG 3.0-3.4 outperforms MG 5.0-5 when compared in the same year

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)

Sensitivity Analyses:

Soybean Price Sensitivity: MG 3.0-3.4 is less profitable at to rise to $6.87 per bushel to be as profitable as MG 5.0-5. could drop to $6.31 per bushel to be as profitable as MG 3

Irrigation Cost Sensitivity: MG 3.0-3.4 is less profitable ar cost would need to rise to $2.42 per acre-inch for MG 3.0-3

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)

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 out 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 warrantie 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 p 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 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 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.

Technical Appendix

Data collected in 2012 and 2013 from a large regional planting-date experiment at 9 locations with a range of latitudes from 30.6 to 38.9°N was used to calibrate cultivar coefficients for DSSAT-CROPGRO, a biophysical crop growth simulation model. The calibration dataset comprised a total of 58 irrigated environments (site x year x planting date combinations) and included phenology measurements taken during the growing season and end-of-season grain yield, seed weight, and seed oil and protein concentration. After calibration, a set of generic coefficients based on MG and determinacy was obtained for MG 3 to 6 cultivars (Table 1). Cultivar coefficients related to prediction of main developmental stages were calibrated first (CSDL, PPSEN, R1PPO, EM-FL, FL-SH, SD-PM) and found to be dependent on the soybean relative MG and plant growth habit (determinacy) (more details in Salmeron and Purcell, 2016). Subsequently, cultivar coefficients related to growth, partitioning and seed oil and protein concentration (Fl-LF, LFMAX, SLAVR, SIZLF, XFRT, WTPSD, SFDUR, SDPDV, PODUR, THRSH, SDPRO, SDLIP) were calibrated by MG following a sequential approach. A modification in the model settings to increase leaf senescence under low irradiance (ICMP and TCMP in the species file) improved model simulations across MGs, and therefore, cultivar coefficients were calibrated after setting ICMP and TCMP to values of 3.5 and 6, respectively. More details in the calibration of the growth cultivar coefficients can be found in Salmeron et al., (2016).

Table 1. Calibrated generic growth coefficients by MG with data from 2012 and 2013 (extracted from Salmeron and Purcell, 2016).

Cultivar coefficients	Definition and units	Calibrated coefficients by MG			
		3	4	5	6
CSDL†	Critical short day length below which reproductive development progresses with no daylength effect (h)	13.40	13.10	12.75	12.45
PPSEN‡	Slope of the relative response of development to photoperiod with time (1/h)	0.285	0.294	0.302	0.311
R1PPO‡	Increase in daylength sensitivity after anthesis, CSDL decreases by this amount (h)	0.324	0.369	0.414	0.459
EM-FL†	Time between plant emergence and flower appearance (R1) (photothermal days)	17.5	17.5	21	21
FL-SH	Time between first flower and first pod (R3) (photothermal days)	6.2	7.3	7.6	8.6
FL-SD†	Time between first flower and first seed (R5) (photothermal days)	14.2	14.2	11.6	11.6
SD-PM†	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	34.4	35.4	32.8	32.8
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)	26.0	19.2	15.0	15.2
LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO_2, and high light (mg CO2/m^2-s)	1.02	0.94	0.92	0.92
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	368.0	359.0	359.8	395.3
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	152.2	199.3	168.2	187.9
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	0.95	1.00	1.00	0.90

cont'd

WTPSD	Maximum weight per seed (g)	0.154	0.158	0.130	0.130
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	19.0	23.9	23.6	23.0
SDPDV	Average seed per pod under standard growing conditions (seeds/pod)	2.28	2.10	2.25	2.36
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	11.84	13.55	10.76	7.52
THRSH	Threshing percentage. The maximum ratio of seed/(seed+shell)) at maturity. Causes seeds to stop growing as their dry weight	76.2	76.0	76.0	76.0
SDPRO	Fraction protein in seeds (g(protein)/g(seed))	0.386	0.391	0.395	0.385
SDLIP	Fraction oil in seeds (g(oil)/g(seed))	0.199	0.198	0.195	0.199

Data collected in the regional planting-date experiment during the subsequent growing season (2014) were used to test the model performance for prediction of main developmental stages with the generic cultivar coefficients calibrated during 2012 and 2013. Data from 2014 included a total of 33 environments across 9 locations and different planting dates. Predictions of main developmental stages in 2014 were more accurate for prediction of beginning flowering (R1) and beginning seedfill (R5) compared to physiological maturity (R7) (Table 2). Overall, the model was able to accurately predict main developmental stages across environments and MG cultivars with a RMSE ranging from 4.4 to 12 days.

Table 2. Root mean square error (RMSE) in prediction of main developmental stages in 2014 with generic cultivar coefficients calibrated during 2012-2013.

MG	RMSE in prediction of developmental stages		
	Beginning flowering (R1)	**Beginning seedfill (R5)**	**Physiological maturity (R7)**
	---------- days ----------		
3	4.8	6.5	7.5
4	4.4	6.7	7.3
5	5.7	5.8	9.9
6	6.0	6.7	12.0

Yield model predictions in 2014 were efficient capturing differences associated with environment and MG choices, with a model efficiency (ME) of 0.40 and a RMSE of 571 kg ha^{-1} or 8.5 bu/acre (Table 3). Positive values of ME indicate that the model was a more efficient predictor than using the observed average across treatments. The model was able to simulate differences in seed oil concentration across environments and MGs (ME = 0.52), but not protein concentration (ME = -0.25). However, the error in prediction of oil and protein concentration was relatively small (normalized RMSE < 5%). Seed oil and protein concentration predictions were not used in SOYMAP but apply to SOYRISK.

Table 3. Average observed, bias (predicted – observed), model efficiency (ME) and root mean square error (RMSE) in the prediction of grain yield, and seed oil and protein concentration by MG in 2014, with generic cultivar coefficients calibrated during 2012-2013.

MG	Obs	Bias	ME	RMSE
	Grain yield (kg ha^{-1})[a]			
3	3633	-196	0.44	514
4	3762	-52	0.55	494
5	3260	345	-0.26	644
6	2831	273	0.29	627
All	3394	83	0.40	571
	Oil concentration in seed (%)			
3	20.2	-0.26	0.15	0.95
4	19.9	-0.36	0.29	0.63
5	19.0	0.00	0.48	0.60
6	18.6	-0.11	0.28	0.91
All	19.5	-0.19	0.52	0.78
	Protein concentration in seed (%)			
3	34.6	-0.15	-0.22	1.54
4	34.9	0.55	-0.19	1.00
5	35.2	0.34	-0.41	1.21
6	35.3	-0.01	-0.65	1.34
All	35.0	0.19	-0.25	1.29

[a] Multiply by 0.149 to convert kg/ha to bu/acre.

The analysis of yield stability was used to further study the model performance capturing genotype (G) x Environment (E) responses across environments in 2014. An environmental index (EI) was calculated as the mean observed yield for an environment minus the grand mean across environments. Predicted and observed yields were then fit to a straight-line regression against the EI (Figure 1). To analyze predictive accuracy across G x E the slopes of the fitted lines on observed and predicted yields should be similar. An analysis of covariance was used to test if the slopes and intercepts of the regressions were affected by the MG and/or the source of the yield data (observed or predicted). The analysis indicated that the slopes of the yield regressions against the EI were only dependent on the MG and were similar ($p = 0.1089$) for the simulated and observed data (Table 4). Simulated yields were significantly different from the observed when EI>0 (as indicated by the * in Figure 1), but yield differences in the higher yielding environments were still relatively small (245 to 608 kg ha^{-1} or 3.7 to 9.1 bu/acre). The results indicate an overall robust model performance for capturing G x E responses with coefficients calibrated by MG.

Table 4: Analysis of covariance for the regression of soybean yield on the environmental index (EI) as an independent variable. Soybean maturity group (MG), yield data source (observed vs. predicted by the model; O vs. P), and the interactions of both were included as factors in the model to test their effect on the intercept and slopes of the regressions.

Regression parameter	Effect	Num DF	Den DF	F value	P-value
Intercept	Maturity group (MG)	3	226	75.7	<.0001
	MG x O vs. P	4	226	7.6	<.0001
Slope	Environmental Index (EI)	1	226	354.04	<.0001
	EI * MG	3	226	7.17	0.0001
	EI * MG * O vs. P	4	226	1.91	0.1089

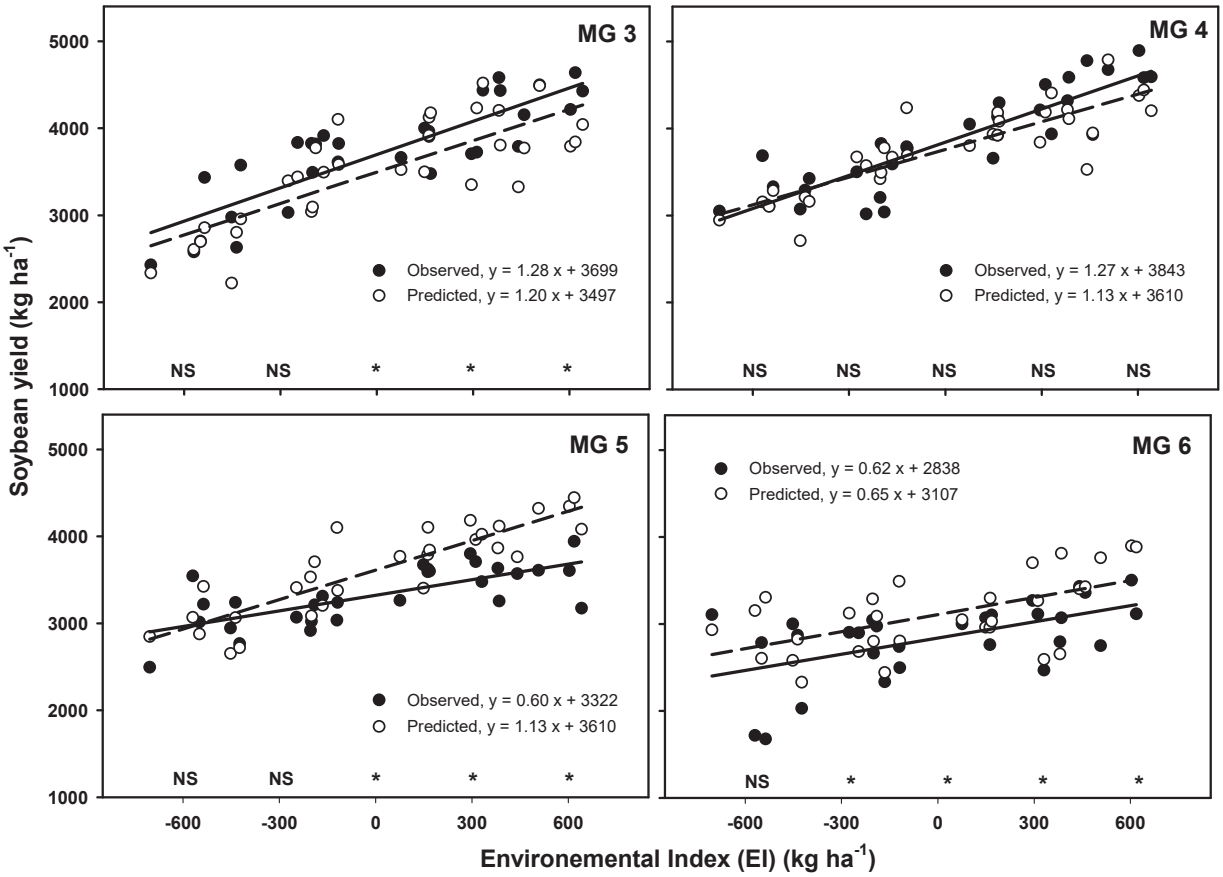


Figure 1: Regression of the observed and simulated yield versus the environmental Index (EI) by MG. Data averaged across cultivars within a MG and environment. The equations show the slope and intercept of the individual regressions by MG and yield data source (observed vs. predicted). The asterisks at different values of the EI indicate significant differences ($p < 0.05$) between observed and predicted yields within a MG.

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