Optimal Planting Date for Soybeans by Maturity Group in Tennessee

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ABSTRACT

The objective of this study was to determine the profit-maximizing planting date for soybeans with four maturity groups (MG) in Tennessee. Net returns were simulated for four maturity groups with four revenue protection (RP) insurance coverage levels to determine the optimal maturity group and coverage level preferred by risk averse producers under two planting intervals. Data were collected from a soybean planting date experiment for MG II, III, IV, and V in Milan, Tennessee from 2008-2010. Limited knowledge exists on estimated soybean yield response to planting date to determine the profit-maximizing planting date for soybean production by maturity group in the southern United States. Furthermore, determining the optimal maturity and coverage level that is preferred by risk averse producers under two planting date windows would be a unique contribution to the literature. The profit-maximizing planting date for soybeans in Tennessee ranged between 13 May and 24 May for all the maturity groups, and specifically, the profit-maximizing planting date was 24 May, 16 May, 13 May, and 22 May for maturity groups II, III, IV, and V, respectively. The risk analysis shows that a risk neutral to slightly risk averse decision maker would prefer maturity group III with no revenue protection; however, as risk averse increased the preferred scenario was maturity group III with 80% revenue protection. The results might help producers determine optimal planting windows and crop insurance options for soybean production in Tennessee based on their risk preferences.

Abbreviations: ARAC, absolute risk-aversion coefficient; CDF, cumulative distribution function; CE, certainty equivalent; MG, maturity group; RMA, Risk Management Agency; RP, revenue protection; SERF, stochastic efficiency with respect to a function; USDA NASS, United States Department of Agriculture National Agricultural Statistic Service

INTRODUCTION

There has been an extensive amount of research on the impact of planting date on soybean (*Glycine max* (L.) Merr.] production, which can be dated back to Mooers (1908) in TN (Carrtter and Hartwig, 1963). Over the years, many studies have concluded that planting date is one of the most important and least expensive production decisions that affects soybean yields and quality; however, this topic still receives a lot of attention by soybean researchers (Egli and Cornelius, 2009; Hu and Wiatrak, 2012). Several related factors such as location, year-to-year climate conditions, and maturity group (MG) selection make determining the optimum planting date for soybeans a complex decision (Egli and Cornelius, 2009; Hu and Wiatrak, 2012).

Egli and Cornelius (2009) used data from 28 experiments located across the United States to analyze the regional impacts (i.e., weather and soil type) on the yield-maximizing planting dates. They present a detailed literature review of soybean planting date studies located in the Midwest (IA, IL, IN, ND, NE, and OH), Upper South (AR, KY, MO, and TN), and Deep South (AL, FL, GA, LA, MS, and SC). They found that soybean yield potential decreased when planted after late May in the Midwest and Deep South regions and after early June in the Upper South region. Yields decreased at a faster rate though in the Deep South and Upper South than in the Midwest after the critical planting dates in late May or early June, respectively. The yield loss from delayed planting is commonly due to decreases vegetation and reproductive growth stage, reduces the number of branches and pods, shorten plant height, and decreases photosynthesis (Popp et al., 2002; Pedersen and Lauer, 2003; Bastidas et al., 2008; De Bruin and Pedersen, 2008); thus, reducing soybean yields. Photoperiod, temperature, and precipitation or combinations of these climatic variables were commonly identified as the primary factors that can delay planting date (Popp et al., 2002; Pedersen and Lauer, 2003; Bastidas et al., 2008; De Bruin and Pedersen, 2008; Egli and Cornelius, 2009; Chen and Wiatrak, 2010).

Planting soybeans earlier in the growing season allows for a longer vegetative and reproductive period (Hu and Wiatrak, 2012), which can decrease insect pressure, disease pressure, and circumvent late-summer drought (Salmeron et al., 2014). However, planting too early has been shown to decrease yield potential by reducing the canopy development (Steele and Grabau, 1997) and delaying seedling emergence (Andales et al., 2000) if the soil is too cold or wet. Early planting of soybeans can also expose a producer to the risk of a late frost, which will negatively impact yield potential (Meyer and Badaruddin, 2001; De Bruin and Pedersen, 2008). Logan et al., 1998 showed that in TN soybean yields were lower when planted between March and April than planted between April June because the earlier planted soybeans were exposed to cooler and moister conditions than the soybeans planted in April through June.

Another important variable to consider when identifying the optimum planting dates is the MG of the soybeans (Boquet, 1998; Egli and Bruening, 2000; Egli and Cornelius, 2009; Chen and Wiatrak, 2010; Salmeron et al., 2014). Chen and Wiatrak (2010) found that the yield maximizing planting date was mid-May for MG IV and early-May to mid-June for MG V in South Carolina. Salmeron et al. (2014) recently analyzed two years of data from 10 locations in the Mid-South (AR, LA, MO, MS, TN, and TX) to determine the relationship between MGs and planting date. When soybeans were planted at the late planting date (May through June), yields decreased by 7% for MG III, 12% for MG IV, 18% MG V, and 11% for MG VI relative to the early planting dates (March through April) . Generally, soybean yields were maximized for MG III through V (i.e., earlier MGs) when planted in April and yield were maximized for MGs V through VII (later MGs) in May and June for the southern United States (Heartherly, 1999;

Heatherly and Elmore, 2004; Egli and Cornelius, 2009), but this relationship between planting date and MG does not hold in northern climates (Kane et al., 1997). Overall, research indicated that the yield maximizing planting date can depend on many environmental factors of the region as well as the MG (Egli and Cornelius, 2009; Chen and Wiatrak, 2010).

While these are informative studies for choosing optimum planting dates for a given MG, the vast majority of these studies evaluated soybean yields at early and late planting dates for different MGs by testing for mean differences (Logan et al., 1998; Popp et al., 2002; Pedersen and Lauer, 2003; Bastidas et al., 2008; De Bruin and Pedersen, 2008; Salmeron et al., 2014). Estimating yield response to planting date using a response function would improve predictions of the optimum planting date by MG. Previous studies have estimated yield response to planting date for corn (Lauer et al., 1999; Darby and Lauer, 2002) and for wheat (Epplin et al., 2000; Hossian et al., 2003); however, limited knowledge exists on soybean yield response to planting date using a response function in the southern United States.

Furthermore, little is known about the profit-maximizing planting date for soybean production in the southern United States. As the planting date window for soybeans is widened in a given year, the cost of production for soybeans does not change across months if inputs are forward contracted. Therefore, the yield-maximizing planting date of soybeans could also be the profit-maximizing planting date. However, net returns to planting dates were rarely reported in the literature (Popp et al., 2002). Popp et al. (2002) estimated the profit-maximizing planting date for soybeans in Arkansas to fall between May and June using an analysis of variances. In our review of literature, no study has estimated soybean yield response to planting date to determine the profit-maximizing planting date for soybeans by MG.

Moreover, the variability of net returns could depend on the planting date window for each MG. Salmeron et al. (2014) showed that early (March and April) and late (May and June) planted soybeans of different MGs can have a substantial impact on yield variability, which will impact the variability of net returns. They found that yields were more stable for MGs IV and V when planted early (March and April) and MGs III and IV when planted late (May and June). Salmeron et al. (2014) stated economic and risk analyses are needed to provide producers with a MG recommendation for a given planting date window. A key component that needs to be considered economic and risk analyses would be the protection provided to producers by purchasing crop insurance. In 2013, soybeans were planted on over 630,000 hectare in TN, making soybeans the number one planted crop in state (United States Department Agriculture Risk Management Agency (USDA RMA), 2014a). Crop insurance was purchased for 84% of the soybean hectares planted in TN in 2013, and of the insured lands, revenue protection (RP) was purchased for 72% of insured soybean hectares (United States Department Agriculture Risk Management Agency (USDA RMA), 2014a). Determining the profit-maximizing MG for different planting windows while considering the variability of net returns in the upper south United States would be a unique and relevant contribution to the existing literature.

Hence, the objective of this research was to determine the optimal planting date to maximize net returns for soybean production for four MGs in TN. Additionally, we simulate net returns for the four MGs with four RP insurance coverage levels to determine the optimal maturity and coverage level that is preferred by risk averse producers under two planting date windows. Data were collected from a soybean planting date experiment for MGs II through V in Milan, TN from 2008-2010. The results of this analysis will aid producers in determining optimal planting windows and crop insurance options for soybean production in TN based on their risk preferences.

MATERIAL AND METHODS

Experimental Data

Soybean yield data were collected from a soybean planting date experiment conducted at the University of TN Milan Research and Education Center (35°56′ N, 88°43′ W) from 2008 to 2010. Non-irrigated soybeans were grown on a Falaya Silt Loam soil, which is well suited for soybean production in TN (USDA Natural Resource Conservation Service, 1999). Soybeans were no-till planted in 38.1 cm rows on plots that were 3.48 m wide and 9.144 m long with seven rows per plot. Five Mg ha^{-1} of lime was applied to the plots in 2010. Soil tests indicated that the P and K levels were within recommended levels; thus, no N-P-K was applied during the experiment. The plot had burn down applications of generic Glyphosate and Dicamba, but no pre-emerge herbicides were applied to avoid any potential injury to soybeans. All plantings received two applications post-emerge of glyphosate. Table 1 shows the average temperature and precipitation by month and year at Milan, TN.

<< Insert Table 1 Approximately Here >>

The experimental design was a split- split-plot design with four replications. The main plots were four MGs, the subplots were two seeding rates, and sub-subplots were seven planting dates. Therefore, a total of 224 observations were collected for each year of the experiment. The MGs were II, III, IV, and V. MG II cultivars were Pioneer 92780, Asgrow 2909, Asgrow 2802, and Pioneer 92M61. MG III cultivars were Pioneer 93Y92, Asgrow 3803, Asgrow 3906, Pioneer 93M90, and Pioneer 93Y90. MG IV cultivars were Pioneer 94Y60, Asgrow 4903, and Pioneer

94B73. MG V cultivars included Asgrow 5567, Armor 53z4, Armor 5567, and Pioneer 95Y70. The seeding rates were 140,000 and 180,000 seeds ha^{-1}. In 2008, planting started on 28 April and occurred on 3 May, 13 May, 3 June, 17 June, 2 July, 15 July, and 29 July. In 2009, soybeans were planted on 17 April, 13 May, 1 June, 23 June, 7 July, 27 July, and 10 August. In 2010, soybeans were planted on 21 April, 7 May, 24 May, 2 June, 16 June, 6 July, and 19 July. Figure 1 shows a plot of the soybean yields by planting date in Julien days by MG. There were a few observations for each of the MGs with near zero yields, which were likely due to late planting and wildlife damage. Table 1 shows the average temperature and precipitation by month and year at Milan, TN.

<< Insert Figure 1 Approximately Here >>

Soybean cash prices for TN were collected from 1990-2013 from USDA National Agricultural Statistic Service (NASS) 2013). These prices were converted into 2013 dollars using the seasonally adjusted annual Gross Domestic Product Implicit Price Deflator (Federal Reserve Bank, 2013). Prices were collected for the harvest months of September, October, and November. There was no difference in real soybean price across the harvest months and the price ranged from \$0.08 to \$0.22 kg^{-1} with an average price of \$0.13 kg^{-1} over the time period. Production costs of \$816 ha^{-1} were assumed from the University of TN Crop Budgets for non-irrigated, no-till soybean production (University of TN Department of Agricultural and Resource Economics, 2014).

Crop insurance was purchased for 84% of all soybean hectares planted in TN in 2013, and of the insured lands, RP was purchased for 72% of insured soybean hectares (USDA Risk Management Agency (RMA), 2014a). Therefore, including RP options in the analysis was representative of soybean production in TN. Crop insurance indemnity payments and producer premiums were found using the USDA RMA calculator (2014b). The indemnity and premium payments were calculated for RP with 60%, 70%, and 80% coverage. Gibson County was selected, which is the location of the experiment. The base yield was assumed to be 2,757 kg ha^{-1}, which is the average soybean yield in Gibson County from 2008-2010 (USDA-NASS, 2013), and the projected price was \$0.16 kg^{-1}. Producer premium amounts were \$22.24, \$39.54, and \$71.66 ha^{-1} for 60%, 70%, and 80% coverage levels, respectively. Maximum indemnity payments were estimated as \$689, \$805, and \$922 kg^{-1} for 60%, 70%, and 80% coverage levels, respectively.

Economic and Statistical Model

Enterprise budgets for soybean production were developed to determine the optimal planting date by MG. The net returns were calculated as

$$(1)\quad R_m = p y_m(D) - C$$

where R_m is the net returns in \$ ha^{-1} for the *m*th MG; p is the price of soybeans in \$ kg^{-1}; y_m is the yield kg ha^{-1} which is a function of planting date; and C is the cost of production \$ ha^{-1}.

Yield response to planting Julian day (starting at 1 January of each year) was estimated for each MG following previous research (Lauer et al., 1999; Epplin et al., 2000; Darby and Lauer, 2002; Hossian et al., 2003). A quadratic response function was estimated since this functional form best represented these data (see Figure 1). The yield response to Julien day for each of the MGs is specified as

$$(2)\quad y_{tm} = \beta_0 + \beta_1 D_t + \beta_2 D_t^2 + v_t + e_{tm}$$

where y_{tm} is soybean yield in kg ha^{-1} in year t for MG m, D_t is Julian day (starting at 1 January of each year); β_0, β_1, and β_2 are coefficients; $v_t \sim N(0, \sigma_v^2)$ is a year random effect; and

$e_{tm} \sim N(0, \sigma_e^2)$ is the random error term. The model was estimated using MIXED procedure in SAS 9.2 (SAS Institute Inc., 2004). Equation (2) is substituted into equation (1) and the first-order condition of equation (1) was taken with respect to planting date (*D*). The first order condition was solved for the profit-maximizing planting date for each MG $D^* = (-\beta_1)/2\beta_2$. Standard errors for the expected profit-maximizing planting date were calculated using the delta method (Greene, 2008; pg. 69), and were used to build confidence intervals for the expected profit-maximizing planting date. The profit-maximizing yield for each MG was solved for by substituting the *D** into equation (2).

Simulation models were built to determine the optimal MG and RP coverage level that is preferred by risk-averse producers under two planting windows. The stochastic net returns were calculated as

$$(3)\quad \tilde{R}_{jm} = \tilde{p} y_m(\tilde{D}_m) - C - w_j + \lambda_j I_j$$

where $\tilde{R}_{jm}$ is the uncertain net returns in \$ ha^{-1} for the *j*th coverage level; $\tilde{p}$ is uncertain price of soybeans in \$ kg^{-1}; y_m is the yield in kg ha^{-1}; $\tilde{D}_m$ is uncertain planting date for a given MG; *C* is the cost of production; w_j is the premium in \$ ha^{-1} for crop insurance; I_j is the indemnity payment in \$ ha^{-1}; and λ_j is a binary variable that is one when crop insurance is triggered for the *j* coverage level.

Parameter estimates for the yield response function in equation (2) were substituted into the simulation model with planting date being randomly drawn from a GRKS distribution from two time periods. The GRKS distribution is useful when minimal information is available about the distribution, requiring only minimum, mid-point, and maximum values as the bounds for the distribution (Richardson, 2006). The first planting date window ranged between 1 May and 31

May with the mid-point at the optimal planting date *D** for each MG. The second planting date window ranged between 1 May and 15 June (cutoff date for crop insurance) with the mid-point at the optimal planting date *D** for each MG. The purpose for the wider planting date window is to show how added planting variability impacts expected net returns. Prices were randomly drawn from an empirical distribution derived from the historical real price data. The four scenarios for RP crop insurance were 1) no crop insurance; 2) 60% coverage; 3) 70% coverage; and 4) 80% coverage. Production costs, crop insurance premiums for the producer, and indemnity payment were deterministic.

Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to develop the distributions and perform the simulations (Richardson et al., 2008). Net returns for each of the four MGs and four crop insurance options were simulated for the two planting windows. Therefore, we simulated a total of 16 net returns probability distributions for each of the planting date windows. A total of 5,000 observations were simulated for each of the scenarios.

Risk Analysis

Incorporating risk into the decision making framework changes the producers' preferences by considering the variability of net returns along with the expected net returns. A common approach to comparing risky scenarios is to use stochastic dominance, which compares the cumulative distribution function (CDF) of net returns for each of the scenarios (Chavas, 2004). In first degree stochastic dominance, the scenario with CDF *F* dominates another scenario with CDF *G* if $F(R) \leq G(R) \forall R$. First degree stochastic dominance often does not find one scenario to clearly be preferred to another; therefore, second degree stochastic dominance adds the restriction that producers are risk averse, which increases the chance of finding a preferable scenario (Chavas, 2004). Second degree stochastic dominance states the scenario with CDF F dominates another scenario with CDF G if $\int F(R)dR \leq \int G(R)dRG(R) \forall R$.

If there is not a clear dominant scenario for MG and revenue coverage level using first and second degree stochastic dominance, stochastic efficiency with respect to a function (SERF) was used to rank the scenarios over a range of absolute risk aversion coefficients (Hardaker et al., 2004). SERF analysis requires the specification of a utility function $U(\tilde{R}_{jm}, r)$, which is a function of the distribution of net returns for each crop insurance coverage level and MG along with an absolute risk-preference level *r*. The utility function was used to find the certainty equivalent (CE), which is defined as the guaranteed return a person is willing to receive rather than taking a gamble for a higher but uncertain return. The MG and RP scenario with the highest CE at a given level of risk was preferred by producers. The CEs were compared at various levels of risk to determine the optimal MG and RP scenario as a producers risk preferences change. Risk-averse producers are willing to take smaller net returns with certainty than the expected value of the net returns with uncertainty.

A negative exponential utility function was used in this analysis, which specifies absolute risk-aversion coefficient (ARAC) to calculate the CE (Pratt, 1964). Following Hardaker et al. (2004), a vector of CEs will be derived bounded by a low and high ARAC. The lower bound ARAC was zero, meaning the producer was risk-neutral and the scenario with the highest expected net returns was preferred. The upper bound ARAC was found by dividing four by the average net returns for all the scenarios, which was proposed by Hardaker et al. (2004) to find the extremely risk averse decision maker. The SERF analysis was also conducted in Simulation and Econometrics to Analyze Risk (SIMETAR©) (Richardson et al., 2008).

RESULTS AND DISCUSSION

Optimal Planting Date

Table 2 shows the results of the yield response function to planting date by MG. The linear and the quadratic parameter estimates for planting date were significant at the 0.01 level for each of the MGs, but the intercept was not significantly different from zero at the 0.05 level. The quadratic shape of the response function indicates that soybean yields were increasing at a decreasing rate as planting date was extended. This matches previous research that soybean yields may not be maximized by planting too early (Steele and Grabau, 1997; Logan et al., 1998; Andales et al., 2000; Meyer and Badaruddin, 2001; De Bruin and Pedersen, 2008) and decrease after a certain planting date (Popp et al., 2002; Pedersen and Lauer, 2003; Bastidas et al., 2008; De Bruin and Pedersen, 2008; Egli and Cornelius, 2009).

<< Insert Table 2 Approximately Here >>

The profit-maximizing planting date for soybeans in TN ranged between 13 May and 24 May for all MGs. Egli and Cornelius (2009) found yields decreased when soybeans were planted after early June in the Upper South region, which included TN, but fall within the profit-maximizing planting dates for soybeans in Arkansas found by Popp et al. (2002). Specifically for each MG, the profit-maximizing planting date was 24 May, 16 May, 13 May, and 22 May for MGs II, III, IV, and V, respectively. The 90% confidence intervals for the expected profit-maximizing planting dates overlap, indicating there was no difference in soybean yield response to planting date across MGs. Producers were found have a long period for planting in TN, which is also found in other southeastern states (Egli and Cornelius, 2009; Chen and Wiatrak, 2010). The profit-maximizing planting date for MG II occurring later in the growing season than the other MGs and the profit-maximizing planting date for MG IV occurring earlier in the growing season than all other MGs were unanticipated results. Typically, the earlier MGs would need earlier planting dates and later MGs need later planting dates; however, the logical order of optimal planting date to MG has not always been found in the literature for Southeast soybean production (Chen and Wiatrak, 2010; Salmeron et al., 2014).

The profit-maximizing yields were 3,399 kg ha^{-1} for MG II, 3,569 kg ha^{-1} for MG III, 2,448 kg ha^{-1} for MG IV, and 3,535 kg ha^{-1} for MG V (Table 2). These profit-maximizing yields were higher than the average county yields where the experiment occurred (USDA-NASS, 2013). Expected net returns were the highest for MG III since MG III had the highest expected profit-maximizing yield (Table 2).

Simulated Net Returns

For the planting window ranged between 1 May and 31 May, the highest expected net returns were found for MG III with no RP coverage (Table 3). A profit-maximizing, risk-neutral producer would grow MG III soybeans and not purchase crop insurance. However, the highest variability of net returns was found for MG III; thus, MG III has the highest expected net returns but also the highest risk (Table 3). Across all coverage levels of revenue protection, the MG III had the highest expected net returns (Table 3). The expected net returns decreased as the coverage level of RP increased. As anticipated, the variability of net returns also decreased as the coverage level of RP increased (Table 3).

<< Insert Table 3 Approximately Here >>

When the planting window was widened to range between 1 May and 15 June, the highest expected net returns and highest variability of net returns were still found for MG III for all RP coverage levels (Table 4). A profit-maximizing, risk-neutral producer would still choose to grow MG III soybeans and not purchase crop insurance. Relative to the shorter planting period, the expected net returns decreased on average when the planting window was widened. This was because more dates beyond profit-maximizing dates were included in the distribution.

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Risk Analysis

The CDFs of the 16 scenarios with the 1 May to 31 May planting window and the CDFs of the 16 scenarios with the 1 May to 15 June crossed multiple times, meaning first and second degree stochastic dominance did not indicate a clear preferable scenario.

SERF was used to determine the preferred MG and RP scenario by decision makers with different levels of risk aversion. Figure 2 shows the SERF ranking of the 16 scenarios for the 1 May and 31 May planting window. The figure shows the CEs for all 16 scenarios across a wide range of ARAC. If a producer has a planting window between 1 May and 31 May, MG III with no RP was preferred until the ARAC was 0.0075. After this ARAC level, the producer would prefer MG III with the purchase of RP coverage of 80%. The second most preferred combination was MG V with no RP until the ARAC was 0.009; then, the producer would prefer MG V with the purchase of RP coverage of 80%. Figure 3 shows the SERF ranking of the 16 scenarios for the 1 May and 15 June planting window. Similarly, MG III with no RP was preferred until the ARAC was 0.0063; then, the producer would prefer MG III with the purchase of RP coverage of 80%.

<< Insert Figure 2 Approximately Here >>

<< Insert Figure 3 Approximately Here >>

The results can be interpreted as less risk-averse and risk-neutral producers would prefer to not purchase RP insurance. As the producer becomes more risk-averse, the RP at 80% coverage was preferred over no crop insurance and the other coverage levels. While RP of 80% coverage was the most expensive policy to purchase, this coverage level insured that producers, in this analysis, would always have a positive net return.

CONCLUSIONS

The objective of this study was to determine the profit-maximizing planting date for soybeans with four MGs in TN. Then, we simulated net returns for the four MGs with four RP insurance coverage levels to determine the optimal maturity and coverage level that is preferred by risk-averse producers under two planting date windows. Data were collected from a soybean planting date experiment for MG II, III, IV, and V in Milan, TN from 2008-2010. The results can assist producers in determining the optimal planting windows and crop insurance options for soybean production in TN based on their risk preferences.

While several studies have evaluated the impact of planting dates for a given MG in the southeastern United States, limited knowledge exists about soybean yield response to planting date using a response function in the southern United States. Additionally, no study has estimated soybean yield response to planting date to determine the profit-maximizing planting date for soybean production by MG in our review of literature. Furthermore, Salmeron et al. (2014) stated that further research was need on the economics of planting date and MG to make recommendations to producers. Therefore, determining the optimal MG and coverage level that is preferred by risk averse producers under two planting date windows is a unique contribution to the literature.

The profit-maximizing planting date for soybeans in TN ranged between 13 May and 24 May for all the MGs, and specifically, the profit-maximizing planting date was 24 May, 16 May, 13 May, and 22 May for MGs II, III, IV, and V, respectively. The 90% confidence intervals for the expected profit-maximizing planting dates overlapped, indicating there was no difference in soybean yield response to planting date across MGs and that producers have a long period for planting in TN, which is also found in other southeastern states (Egli and Cornelius, 2009; Chen and Wiatrak, 2010). The SERF analysis shows that a risk neutral to slightly risk-averse decision maker would prefer MG III with no revenue protection; however, as risk aversion increased the preferred scenario was MG III with 80% revenue protection.

REFERENCE

Andales, A.A., W.D. Batchelor, and C.E. Anderson. 2000. Modification of a soybean model to improve soil temperature and emergence date prediction. Trans. ASAE 43:121–129.

Bastidas, A.M., T.D. Setiyono, A. Dobermann, K.G. Cassman, R.W. Elmore, G.L. Graef, and J.E. Specht. 2008. Soybean sowing date: The vegetative, reproductive, and agronomic impacts. *Crop Sci.* 48:727–740.

Boquet, D.J. 1998. Yield and risk utilizing short-season soybean production in the mid-southern USA. *Crop Sci.* 38:1004–1011.

Cartter, J., and E.E. Hartwig. 1963. The management of soybeans. p. 161–226. In A.G. Norman (ed.) The soybean: Genetics, breeding, physiology, nutrition, management. Academic Press, New York.

Chavas, J.P. 2004. Risk analysis in theory and practice. San Diego, CA: Elsevier.

Chen, G., and P. Wiatrak. 2010. Soybean development and yield are influenced by planting date and environmental conditions in the Southeastern Coastal Plain, United States. *Agron. J.* 102:1731-1737.

Darby, H.M., and J.G. Lauer. 2002. Planting date and hybrid influence on corn forage yield and quality. *Agron. J.* 94:281-289.

De Bruin, J.L., and Pedersen, P. 2008. Soybean seed yield response to planting date and seeding rate in the upper Midwest. *Agron. J.* 100:696-703.

Egli, D.B., and W.P. Bruening. 2000. Potential of early-maturing soybean cultivars in late plantings. *Agron. J.* 92:532–537.

Egli, D.B., and Cornelius, P.L. 2009. A regional analysis of response of soybean yield to planting date. *Agron. J*. 101:330-335.

Epplin, F.M., I. Hossain, and E.G. Krenzer Jr. 2000. Winter wheat fall-winter forage yield and grain yield response to planting date in a dual-purpose system. *Agric. Systems* 63:161-173.

Federal Reserve Bank of St. Louis. 2013. Gross Domestic Product: Implicit Price Deflator. Available at: http://research.stlouisfed.org/fred2/series/GDPDEF/.

Greene, W.H. 2008. *Econometric Analysis*. 6th ed. Upper Saddle River, NJ: Prentice-Hall.

Hardaker, B.H, J.W. Richardson, G. Lien., and K.D. Schumann. 2004. Stochastic efficiency analysis with risk aversion bounds: A simplified approach. *Australian J. Agric. Resource Econ*. 48:2 253-270.

Heatherly, L.G. 1999. Early soybean production system (ESPS). p. 103–118. *In* L.G. Heatherly and H.F. Hodges (ed.) Soybean production in the Mid-South. CRC Press, Boca Raton, FL.

Heatherly, L.G., and R.W. Elmore. 2004. Managing inputs for peak production. p. 451–536. In H.R. Boerma and J.E. Specht (ed.) Soybeans: Improvement, production, and uses. 3rd ed. ASA, CSSA, and SSSA,Madison, WI.

Hossian, I., F.M. Epplin, and E.G. Krenzer, Jr. 2003. Planting date influence on dual purpose winter wheat forage yield, grain yield, and test weight. *Agron. J.* 95:1179-1188.

Hu, M., and P. Wiatrak. 2012. Effect of planting date on soybean growth, yield, and grain quality: a review. *Agron. J.* 104:785-7980.

Kane, M.V., C.C. Steele, and L.J. Grabau. 1997. Early-maturing soybean cropping system.1. Yield responses to planting date. *Agron. J.* 89:454–458.

Lauer, J.G., P.R. Carter, T.M. Wood, G. Diesel, D.W. Wiersma, R.E. Rand, and M.J. Mlynarek. 1999. Corn hybrid response to planting date in the Northern Corn Belt. *Agron. J.* 91:834-839.

Logan, J., M.A. Mueller, and C.R. Graves. 1998. A comparison of early and recommended soybean production systems in Tennessee. *J. Prod. Agric.* 11(3):319-325.

Meyer, D.W., and M. Badaruddin. 2001. Frost tolerance of ten seedling legume species at four growth stages. *Crop Sci.* 41:1838–1842.

Mooers, C.A., 1908. The soybean: a comparison with cowpea. Bull. 82 Tennessee Agricultural Experiment Station. Knoxville, TN.

Pedersen, P., and J.G. Lauer. 2003. Soybean agronomic response to management systems in the upper Midwest. *Agron. J*. 95:1146–1151.

Popp, M.P., T.C. Keisling, R.W. McNew, L.R. Oliver, C.R. Dillion, and R.W. Wallace. 2002. Planting date, cultivar, and tillage system effects on dry land soybean production. *Agron. J.* 94:81–88.

Pratt, J.W. 1964. Risk aversion in the small and in the large. *Econometrica* 32:122–36.

Richardson, J. W. 2006. Simulation for applied risk management. Unnumbered staff report, Department of Agricultural Economics, Agricultural and Food Policy Center, Texas A&M University, College Station, Texas.

Richardson, J.W., K.D. Schumann, and P. A. Feldman. 2008. SIMETAR Simulation for Excel to Analyze Risk. Department of Agricultural Economics, Agricultural and Food Policy Center, Texas A&M University, College Station, Texas.

Salmeron, M., Gbur, E.E., Bourland, F.M., Buehring, N.W., Earnest, L., Fritschi, F.B., Golden, B.R., Hathcoat, D., Lofton, J., Miller, T.D., Neely, C., Shannon, G., Udeigwe, T.K., Verbree, E.D. Vories, W.J. Wiebold, and L.C. Purcell. 2014. Soyebean maturity group choices for early and late planting in the Midsouth. *Agron. J.* 106:1893-1901.

SAS Institute Inc. *SAS OnlineDoc® 9.1*. Cary, NC: SAS Institute Inc., 2003

Steele, C.C., and L.J. Grabau. 1997. Planting dates for early-maturing soybean cultivars. *Agron. J*. 89:449-453.

United States Department of Agriculture Natural Resource Conservation Service (USDA-NRS). 1999. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. Agricultural Handbook 436, Washington, DC.

United States Department of Agriculture National Agricultural Statistics Service (USDA–NASS). 2014. Quick Stats. Available at: http://quickstats.nass.usda.gov.

United States Department of Agriculture Risk Management Agency. 2014a. 2013 Tennessee Crop Insurance Profile. Available at: http://www.rma.usda.gov/pubs/2014/stateprofiles/tennessee13.pdf.

United States Department of Agriculture Risk Management Agency. 2014b. Cost Estimator. Available at: https://ewebapp.rma.usda.gov/apps/costestimator/Estimates/DetailedEstimate.aspx.

University of Tennessee Department of Agricultural and Resource Economics. 2014. Field Crop Budgets. University of Tennessee-Knoxville Available at: http://economics.ag.utk.edu/budgets.html.

Table 1. Summary of growing-season precipitation (cm), Milan, Tennessee, 2008-2010.

Month†	2008	2009	2010
	Precipitation (in cm)		
April	0.56	3.45	9.53
May	23.77	22.96	53.42
June	3.86	5.64	8.20
July	7.92	20.09	15.06
August	1.88	5.66	5.00
September	1.09	11.23	0.91
October	6.50	20.78	0.46
November	0.00	3.38	---‡
Total	45.67	93.73	92.63
	Temperature (^oC)		
April	10.46	19.14	16.88
May	19.15	19.93	21.77
June	25.25	25.99	27.54
July	26.61	24.57	27.58
August	25.14	24.48	27.84
September	22.69	22.41	23.10
October	15.06	13.90	16.24
November	15.06	11.07	---‡
Average	21.83	20.26	24.16

† NOAA, Milan, TN weather station.

‡ Not applicable.

Table 2. Estimates for soybean yield response to planting date by maturity group in Tennessee

	Maturity Group			
Parameter Estimates	II	III	IV	V
Intercept (β_0)	−5,790.38	−3,467.8	−2,361.79	−4,740.73
D (β_1)	127.04***	103.30***	87.43***	117.48***
D^2 (β_2)	−0.471***	−0.404***	−0.336***	−0.404***
Optimal Date	24 May	16 May	13 May	22 May
90% Confidence Interval	20 April to 25 June	13 April to 16 June	7 April to 15 June	19 April to 19 June
Optimal Yield (kg ha^{-1})	3,399.54	3,569.01	3,447.96	3,535.39
Optimal Net Returns ($ ha^{-1})	$294.53	$349.54	$310.02	$338.64

*** indicate significance at the 0.01 levels.

Table 3. Simulated net returns ($ ha^{-1}) for soybeans planted between May 1 and May 31 by maturity group and revenue protection coverage level in Tennessee

	Maturity Group			
Option	II	III	IV	V
No Crop Insurance	$282.92 (315.51)	$342.49 (331.70)	$303.82 (320.43)	$329.92 (328.71)
60% Revenue Protection	$262.16 (313.48)	$320.28 (331.65)	$282.22 (319.56)	$307.85 (328.43)
70% Revenue Protection	$261.27 (294.58)	$313.41 (318.82)	$279.31 (302.54)	$302.44 (314.0)
80% Revenue Protection	$259.49 (265.96)	$307.11 (292.38)	$275.73 (274.71)	$297.00 (287.09)

Note: standard deviations in parentheses.

Table 4. Simulated net returns ($ ha^{-1}) for soybeans planted between May 1 and June 15 by maturity group and revenue protection coverage level in Tennessee

	Maturity Group			
Option	II	III	IV	V
No Crop Insurance	$276.17 (314.18)	$332.51 (329.47)	$293.76 (318.55)	$321.19 (325.89)
60% Revenue Protection	$255.86 (311.56)	$310.54 (329.05)	$272.59 (317.12)	$299.32 (325.37)
70% Revenue Protection	$255.64 (292.03)	$304.64 (315.19)	$270.68 (299.13)	$294.65 (310.15)
80% Revenue Protection	$254.47 (263.15)	$299.13 (288.28)	$268.09 (270.83)	$289.93 (282.84)

Note: standard deviations in parentheses.

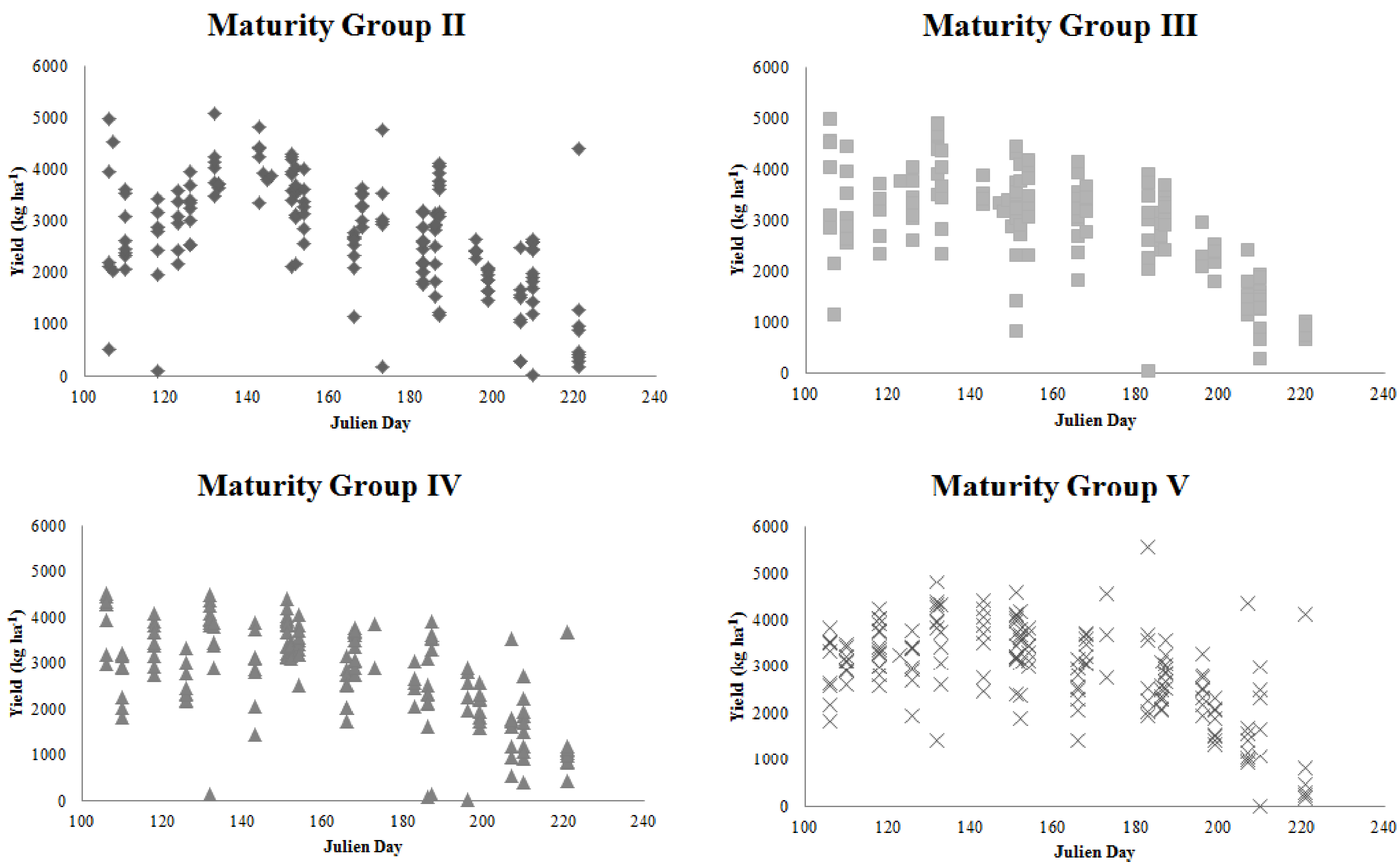

Figure 1. Soybean yields by planting date (Julien day starting January 1) and maturity group from 2008-2010 at Milan, Tennessee

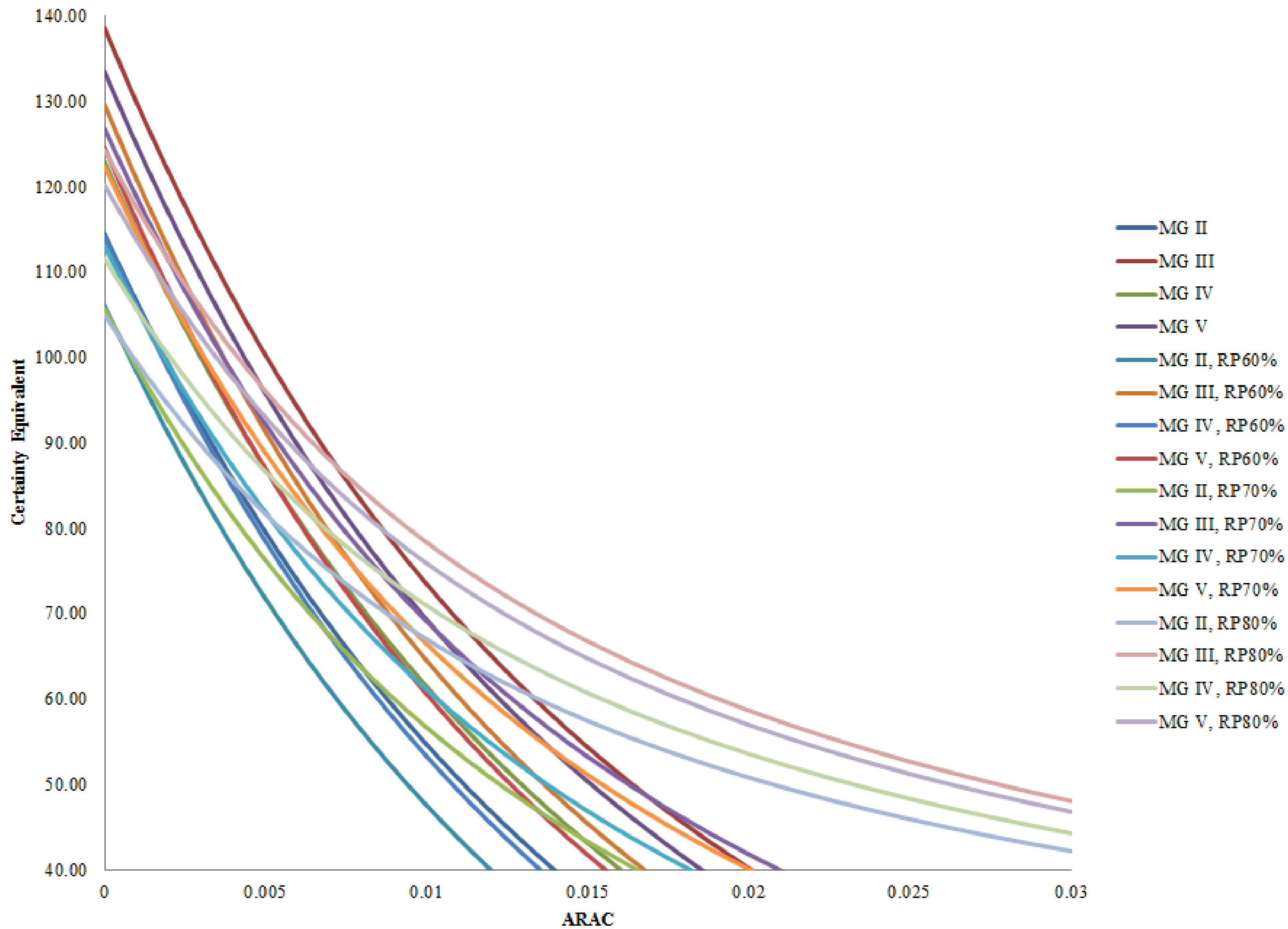

Figure 2. Stochastic efficiency with respect to a function under a negative utility exponential utility function for soybeans planted between 1 May and 31 May by maturity group (MG) and revenue protection (RP) coverage level

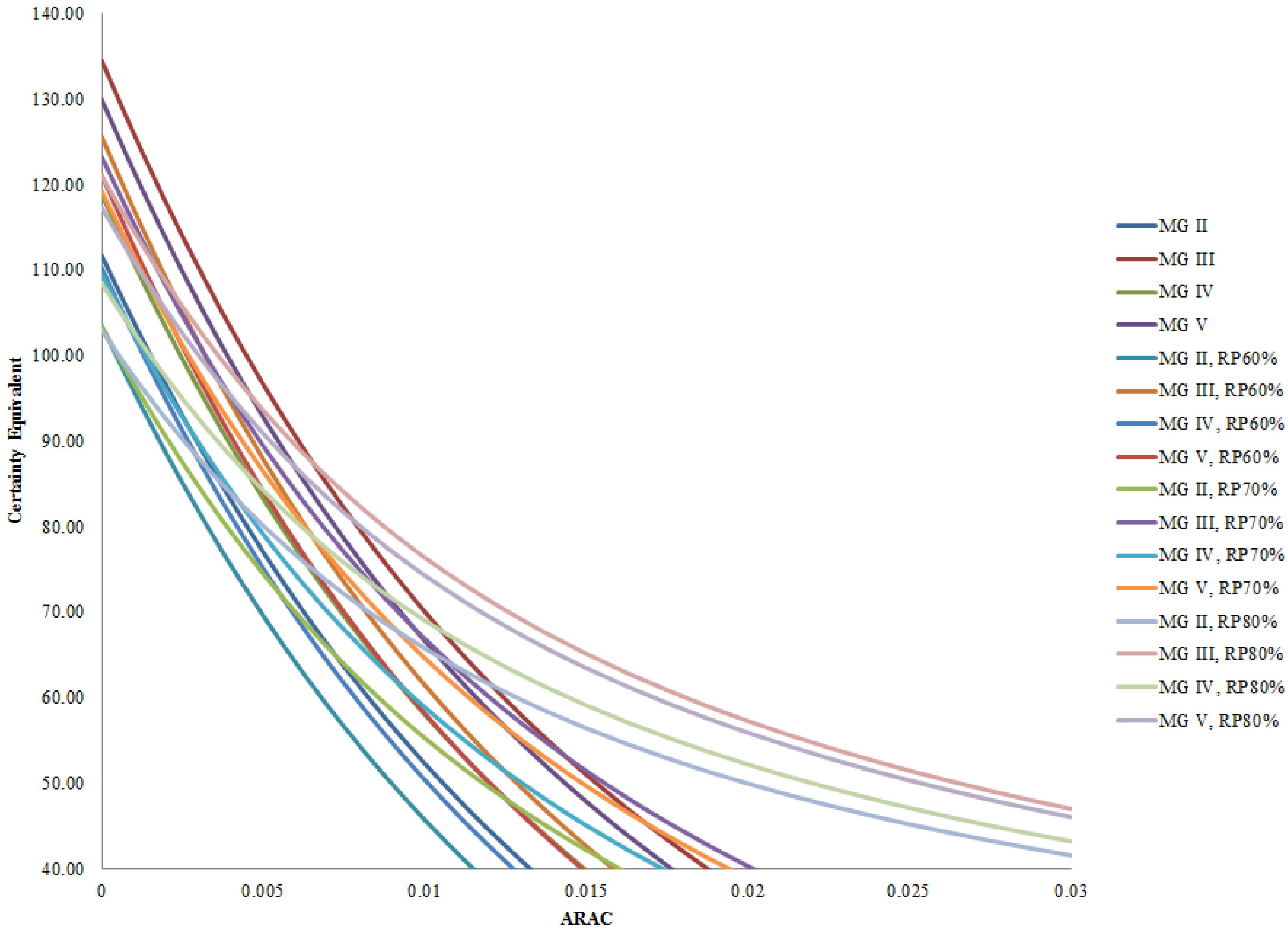

Figure 3. Stochastic efficiency with respect to a function under a negative utility exponential utility function for soybeans planted between 1 May and 15 June by maturity group (MG) and revenue protection (RP) coverage level.