Limited knowledge exists regarding the yield response of soybean [Glycine max (L.) Merr.] from different maturity groups (MGs) to planting date in the southern United States. This information is needed to determine optimal planting dates for each MG. Our objective was to determine the optimum planting date for soybean in MG II, III, IV, and V in western Tennessee while considering producers’ risk preference. Net returns for each MG with four revenue protection (RP) insurance coverage levels were simulated using planting date–yield response functions for each MG. A multiyear experiment (2008–2010) was conducted on MG II, III, IV, and V planted at different dates in Milan, TN. The profit-maximizing planting dates for soybean in western Tennessee were 24 May, 16 May, 13 May, and 22 May for MG II, III, IV, and V, respectively. The confidence intervals for the expected profit-maximizing planting dates across MGs overlapped, suggesting that Tennessee producers have a long period for planting. Risk-neutral to slightly risk-averse producers would prefer MG III with no RP, but as the risk aversion increased, the preferred management strategy was MG III with 80% RP. These results will help producers determine optimum planting windows and crop insurance options for soybean production in West Tennessee based on their risk preferences.
with delayed planting (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 soybean early allows longer vegetative and reproductive periods (Hu and Wiatrak, 2012), which can reduce insect and disease pressures and circumvent late-summer drought (Salmeron et al., 2014). However, planting soybean too early has been shown to decrease yields through reduced canopy development (Steele and Grabau, 1997) and delayed seedling emergence (Andales et al., 2000) if the soil is too cold or wet. Early planting of soybean can also expose the crop to late frosts, negatively impacting yields (Meyer and Badaruddin, 2001; De Bruin and Pedersen, 2008). Logan et al. (1998) found that soybean yields in Tennessee were lower when planted between March and April than between April and June because early-planted soybean was exposed to colder and wetter conditions than soybean planted later in the year.

Cultivar maturity is another important factor influencing the optimum planting date for soybean (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) analyzed 2 yr of data from 10 locations in the Mid-South (Arkansas, Louisiana, Missouri, Mississippi, Tennessee, and Texas) to determine the relationship between MG and planting date. When soybean was planted later (May–June), yields decreased by 7% for MG III, 12% for MG IV, 18% for MG V, and 11% for MG VI relative to planting early (March–April). Generally, soybean yields were maximized for MGs III through V (i.e., earlier MGs) when planted in April, and yields were maximized for MGs V through VII (later MGs) planted in May and June for the southern United States (Heatherly, 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 indicates that a yield-maximizing planting date depends on many regional environmental factors as well as MG (Egli and Cornelius, 2009; Chen and Wiatrak, 2010).

While these studies are informative for choosing optimum planting dates for a given MG, most of these studies evaluated soybean yield response by testing for mean yield differences (e.g., 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 a yield response function would improve predictions of the optimum planting date by MG. Previous studies have estimated corn (Zea mays L.) (Lauer et al., 1999; Darby and Lauer, 2002) and wheat (Triticum aestivum L.) (Epplin et al., 2000; Hossain et al., 2003) yield response to planting date, but limited knowledge exists regarding yield response functions for soybean in the southern United States.

Furthermore, little is known about the profit-maximizing planting date for soybean in the southern United States. As the planting window for soybean is widen in a given year, production costs and soybean prices do not change across months if inputs are forward contracted. Therefore, yield-maximizing soybean planting dates could also be profit-maximizing planting dates. However, net returns to planting dates have rarely been reported (Popp et al., 2002). Popp et al. (2002) estimated the profit-maximizing planting date for soybean in Arkansas as being between May and June using an analysis of variance. In our review of the literature, we found no study that had estimated the soybean yield response to planting date to determine the profit-maximizing planting date for soybean by MG.

We hypothesized that the variability of net returns in response to planting date could differ for each MG. Salmeron et al. (2014) showed that early (March and April) and late (May and June) planting can have a substantial impact on the yield variability of different soybean MGs and thus impact net returns. They found that yields were more stable for MGs IV and V when planted early (March and April) and for MGs III and IV when planted late (May and June). Salmeron et al. (2014) stated that 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 in economic and risk analyses would be the protection provided to producers by the purchase of crop insurance. In 2013, soybean was planted on >630,000 ha in Tennessee, making soybean the number one planted crop in the state (USDA Risk Management Agency, 2014a). Crop insurance was purchased for 84% of the soybean area in Tennessee in 2013, and of the ensured lands, revenue protection (RP) was purchased for 72% of the ensured soybean area (USDA Risk Management Agency, 2014a).

Determining the optimal MG for different planting windows while considering the variability of net returns in the Upper South United States would provide useful information to farmers and contribute new information to the literature regarding planting date for soybean. Hence, our objectives were: (i) to determine the optimal planting date to maximize soybean net returns considering cultivar maturity, and (ii) to assess the risk (i.e., variability) and expected net return trade-offs due to planting date, MG, and crop insurance coverage.

**MATERIAL AND METHODS**

**Experimental Data**

Soybean yield data were collected from a planting date experiment conducted at the University of Tennessee Research and Education Center, Milan, TN (35°56'N, 88°43’W) from 2008 to 2010. Unirrigated soybean was grown on a Falaya silt loam soil (a coarse-silty, mixed, active, acid, thermic Fluvaquent), which is well suited for soybean production in Tennessee (Soil Survey Staff, 1999). The crop was 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. Lime was applied to the plots in 2010 at 5 Mg ha⁻¹. Soil tests indicated that the P and N, 88°C) from...
(II, III, IV, and V), the subplots were two seeding rates, and sub-subplots were seven planting dates. Therefore, a total of 224 experimental units were studied for each year of the experiment. Four MGs were planted in the experiment: MG II (Pioneer 92780, Asgrow 2909, Asgrow 2802, and Pioneer 92M61), MG III (Pioneer 93Y92, Asgrow 3803, Asgrow 3906, Pioneer 93M90, and Pioneer 93Y90), MG IV (Pioneer 94Y60, Asgrow 4903, and Pioneer 94B73), and MG V (Asgrow 5567, Armor 53Z4, Armor 5567, and Pioneer 95Y70). The seeding rates were 140,000 and 180,000 seeds ha⁻¹. In 2008, soybean was planted on 3 and 13 May, 3 and 17 June, and 2, 15, and 29 July. The planting dates for 2009 were 17 April, 13 May, 1 and 23 June, 7 and 27 July, and 10 August. Soybean was planted in 2010 on 21 April, 7 and 24 May, 2 and 16 June, and 6 and 19 July. Figure 1 shows soybean yields by planting date as Day of the Year (DOY) by MG. Seeding rate was not considered in the analysis because yields were not impacted by seeding rates and soybean did not respond to various seeding rates in Tennessee (Thompson et al., 2015). There were a few observations for each of the MGs with near-zero yields, which were probably due to late planting and wildlife damage.

Soybean cash prices for Tennessee were collected for 1990 to 2013 from the National Agricultural Statistics Service (2014) to calculate net returns for selling on the cash market. These prices were converted into 2013 US dollars using the seasonally adjusted annual Gross Domestic Product Implicit Price Deflator (Federal Reserve Bank of St. Louis, 2013). Prices were collected for the harvest months of September, October, and November. There was no difference in the real soybean price across the harvest months, and the price ranged from US$0.19 to US$0.52 kg⁻¹, with an average price of US$0.33 kg⁻¹ during the time period (Fig. 2). Production costs of US$816 ha⁻¹ were assumed from the University of Tennessee crop budgets for unirrigated, no-till soybean production (University of Tennessee Department of Agricultural and Resource Economics, 2014).

Crop insurance premiums for producers were found using the online cost calculator (USDA Risk Management Agency, 2014b). This is an online tool commonly used in the literature to estimate a general premium cost for RP by the producer (Dalton et al., 2004; Wilson et al., 2009; Barham et al., 2011). The premium costs 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 2757 kg ha⁻¹, which is the average soybean yield in Gibson County from 2008 to 2010 (National Agricultural Statistics Service, 2014), and the Risk Management Agency cost calculator assumed a 2013 projected price of US$0.42 kg⁻¹, which was used to determine indemnity payments. Producer premium amounts were US$22.24, US$39.54, and US$71.66 ha⁻¹ for 60, 70, and 80% coverage levels, respectively. Maximum indemnity payments were estimated as US$689, US$805, and US$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

where

\[ R_m = p y_m (D) - C \]  

[1]

where \( R_m \) is the net returns (in US$ ha⁻¹) for the \( m \)th MG; \( p \) is the cash price of soybean (in US$ kg⁻¹); \( y_m \) is the yield (in kg ha⁻¹), which is a function of \( D \), the planting date; and \( C \) is the cost of production (in US$ ha⁻¹).

Yield response to planting DOY (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; Hessain et al., 2003). A quadratic response function was estimated because this functional form best represented these data (see Fig. 1). The yield response to DOY for each of the MGs was specified as

\[ y_m = \beta_0 + \beta_1 D + \beta_2 D^2 + v_i + e_{tm} \]  

[2]

where \( y_m \) is the soybean yield (in kg ha⁻¹) in the \( t \)th year for the \( m \)th MG, \( D \) is the day of the year (starting at 1 January of each year); \( \beta_0, \beta_1, \) and \( \beta_2 \) are coefficients; \( v_i \sim N(0,\sigma^2_v) \) is a year random effect; and \( e_{tm} \sim N(0,\sigma^2_e) \) is the random error term. The model was estimated using MIXED procedure in SAS 9.2 (SAS Institute, 2004). Equation [2] was substituted into Eq. [1], and the first-order condition of Eq. [1] was taken with respect to planting date (\( D \)). The first-order condition was solved for the profit-maximizing planting date (\( D^* \)) for each MG as \( D^* = (–\beta_1/2\beta_2) \). Standard errors for the expected profit-maximizing planting date were calculated using the delta method and were used to estimate confidence intervals for the expected profit-maximizing planting date (Greene, 2008, p. 69). The profit-maximizing yield for each MG was determined by substituting \( D^* \) into Eq. [2].

### Table 1. Summary of growing-season precipitation and temperature as recorded by the NOAA weather station at Milan, TN, 2008 to 2010.

<table>
<thead>
<tr>
<th>Month</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>30-yr avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precipitation, cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr.</td>
<td>0.56</td>
<td>3.45</td>
<td>9.53</td>
<td>12.28</td>
</tr>
<tr>
<td>May</td>
<td>23.77</td>
<td>22.96</td>
<td>53.42</td>
<td>16.12</td>
</tr>
<tr>
<td>June</td>
<td>3.86</td>
<td>5.64</td>
<td>8.20</td>
<td>11.00</td>
</tr>
<tr>
<td>July</td>
<td>7.92</td>
<td>20.09</td>
<td>15.06</td>
<td>11.18</td>
</tr>
<tr>
<td>Aug.</td>
<td>1.88</td>
<td>5.66</td>
<td>5.00</td>
<td>7.21</td>
</tr>
<tr>
<td>Sept.</td>
<td>1.09</td>
<td>11.23</td>
<td>0.91</td>
<td>10.86</td>
</tr>
<tr>
<td>Oct.</td>
<td>6.50</td>
<td>20.78</td>
<td>0.46</td>
<td>9.47</td>
</tr>
<tr>
<td>Nov.</td>
<td>0.00</td>
<td>3.38</td>
<td>–†</td>
<td>12.39</td>
</tr>
<tr>
<td>Total</td>
<td>45.67</td>
<td>93.73</td>
<td>92.63</td>
<td>90.51</td>
</tr>
<tr>
<td></td>
<td>Temperature, °C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr.</td>
<td>10.46</td>
<td>19.14</td>
<td>16.88</td>
<td>14.84</td>
</tr>
<tr>
<td>May</td>
<td>19.15</td>
<td>19.93</td>
<td>21.77</td>
<td>19.73</td>
</tr>
<tr>
<td>June</td>
<td>25.25</td>
<td>25.99</td>
<td>27.54</td>
<td>24.07</td>
</tr>
<tr>
<td>July</td>
<td>26.61</td>
<td>24.57</td>
<td>27.58</td>
<td>26.00</td>
</tr>
<tr>
<td>Aug.</td>
<td>25.14</td>
<td>24.48</td>
<td>27.84</td>
<td>25.45</td>
</tr>
<tr>
<td>Sept.</td>
<td>22.69</td>
<td>22.41</td>
<td>23.10</td>
<td>21.35</td>
</tr>
<tr>
<td>Oct.</td>
<td>15.06</td>
<td>13.90</td>
<td>16.24</td>
<td>14.85</td>
</tr>
<tr>
<td>Nov.</td>
<td>15.06</td>
<td>11.07</td>
<td>–</td>
<td>9.69</td>
</tr>
<tr>
<td>Avg.</td>
<td>21.83</td>
<td>20.26</td>
<td>24.16</td>
<td>19.49</td>
</tr>
</tbody>
</table>

† Not applicable.
Fig. 1. Soybean yields by planting date (Day of the Year starting 1 Jan.) and maturity group from 2008 to 2010 at Milan, TN.
Simulation was used to determine the optimal MG and RP coverage level that is preferred by risk-averse producers under two planting windows. Stochastic net returns were simulated using

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

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

Parameter estimates for the yield response function in Eq. [2] were substituted into the simulation model (Eq. [3]), with planting date being randomly drawn from a GRKS distribution for two planting windows. A planting-date window was defined as the days available for the producer to plant in a production year. The GRKS distribution is useful when minimal information is available about the distribution, requiring only minimum, midpoint, and maximum values as the bounds for the distribution (Richardson, 2006). The GRKS distribution is a two-piece normal distribution with 50% of the observations below the midpoint and 2.5% below the minimum value, while 50% of the observations are above the midpoint and 2.5% above the maximum value (Richardson, 2006). The first planting date window ranged between 1 and 31 May, with the midpoint at the optimal planting date \(D^*\) for each MG. The second planting date window ranged between 1 May and 15 June (the cutoff date for crop insurance), with the midpoint at the optimal planting date \(D^*\) for each MG. The purpose of the wider planting date window was to show how added planting variability impacts expected net returns. The soybean cash price was randomly drawn from an empirical distribution derived from the historical real price data (1990–2013 price data, adjusted to 2013 US dollars). The four management strategies for RP crop insurance were: (i) no crop insurance; (ii) 60% coverage; (iii) 70% coverage; and (iv) 80% coverage. Production costs, crop insurance premiums for the producer, and indemnity payments 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 each of the two planting windows. Therefore, we simulated a total of 16 net return probability distributions for each of the planting-date windows. A total of 5000 observations were simulated for each of the management strategies per planting date.

**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 management strategies is to use stochastic dominance, which compares the cumulative distribution function (CDF) of net returns for each of the management strategies (Chavas, 2004). In first-degree stochastic dominance, the management strategy with CDF \(F\) dominates another management strategy with CDF \(G\) if \(F(R) \leq G(R)\) for all \(R\). First-degree stochastic dominance often does not find one management strategy 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 management strategy (Chavas, 2004).

Second-degree stochastic dominance states that the management strategy with CDF \(F\) dominates another management strategy with CDF \(G\) if \(\int F(R) dR \leq \int G(R) dR\) for all \(R\). More detailed explanation can be found on first- and second-degree stochastic dominance in Chavas (2004), and a graphical expression of the mathematics is shown in Stanger et al. (2008).

If there was not a clear dominant management strategy for MG and RP coverage level using first- and second-degree stochastic dominance, stochastic efficiency with respect to a function (SERF) was used to rank the management strategies across a range of absolute risk aversion coefficients (Hardaker et al., 2004). A SERF analysis requires the specification of a utility function \(U(\tilde{R}, r)\), 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 that a person is willing to receive rather than taking a gamble for a higher but uncertain return. The MG and RP management strategy with the highest CE at a given level of risk is preferred by producers. The CEs are compared at various levels of risk to determine the optimal MG and RP management strategy as a producer’s risk preferences change. Risk-averse producers are willing to take smaller net returns with certainty than the greater expected value of the net returns with uncertainty.

A negative exponential utility function was used in this analysis, which specifies a constant absolute risk-aversion coefficient (ARAC) to calculate the CE (Pratt, 1964). The ARAC represents the ratio of derivatives of the person’s utility function \(v(R) = -U'(R)/U''(R)\). Following Hardaker et al. (2004), a
vector of CEs was derived bounded by a low and high ARAC. The lower bound ARAC was zero, meaning the producer was risk neutral and the management strategy 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 management strategies, which was proposed by Hardaker et al. (2004) to find the extremely risk-averse decision-maker. In our analysis, ARACs ranged from 0.0 as risk neutral to 0.03 as extremely risk averse. This means that as the ARAC increases, the decision-maker is becoming more risk averse. Taking the difference between CEs of any two alternatives is defined as the risk premium. The risk premium is the minimum amount of money a decision-maker would have to be paid to switch from the management strategy with the greatest CE to the alternative management strategy with the lesser CE. For example, if the CE for MG III was US$55 ha−1 and the CE for MG V was US$50 ha−1, the producer would need to be paid US$5 ha−1 to switch from growing MG III to grow MG V. The SERF analysis was also conducted in SIMETAR (Richardson et al., 2008). The SERF analysis is a common method used in agronomic research on risk assessment of row crop production (Archer and Reicosky, 2009; Williams et al., 2010; Barham et al., 2011; Varner et al., 2011).

### RESULTS AND DISCUSSION

#### Optimal Planting Date

Table 2 shows the results of the yield response function (Eq. [2]) 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. The quadratic shape of the parameter estimates for planting date were significant at the 0.01 level for each of the MGs. The linear and the quadratic parameter estimates in Eq. [2] were substituted into Eq. [1] to find the profit-maximizing planting date. The profit-maximizing planting date for soybean ranged between 13 and 24 May for all MGs. Egli and Cornelius (2009) found that yields decreased when soybean was planted after early June in the Upper South region, which includes Tennessee. The profit-maximizing planting dates for soybean in this study also fell within the range reported by Popp et al. (2002) for Arkansas.

The profit-maximizing planting dates were 24 May, 16 May, 13 May, and 22 May for MGs II, III, IV, and V, respectively. 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, early MGs need earlier planting dates than later MGs, but the logical order of optimum planting date by MG has not always been found, especially for US Southeast soybean production (Chen and Wiatrak, 2010; Salmeron et al., 2014). The 90% confidence intervals for the expected profit-maximizing planting dates overlap, indicating that there was no difference in profit-maximizing planting date across MGs. Producers were found to have a long period for planting in Tennessee, which has also been found for other southeastern states (Egli and Cornelius, 2009; Chen and Wiatrak, 2010).

The profit-maximizing yields were 3399 kg ha−1 for MG II, 3569 kg ha−1 for MG III, 2448 kg ha−1 for MG IV, and 3535 kg ha−1 for MG V (Table 2). These profit-maximizing yields were higher than the average country yields where the experiment occurred (National Agricultural Statistics Service, 2014). Expected net returns were the highest for MG III because MG III had the highest expected profit-maximizing yield (Table 2). The average price of soybean of US$0.33 kg−1 was used to find the profit-maximizing net returns (Table 2). The profit-maximizing net returns were US$305 ha−1 for MG II, US$361 ha−1 for MG III, US$321 ha−1 for MG IV, and US$350 ha−1 for MG V (Table 2). At the optimal planting date, the net returns were maximized using MG III.

#### Simulated Net Returns

Parameter estimates for the yield response function in Eq. [2] were substituted into the simulation model (Eq. [3]) to find the net returns for a given planting window. Table 3 presents the summary statistics of the simulated net returns for soybean planted between 1 and 31 May by MG and RP coverage level. By purchasing RP, a producer can reduce the variation in net returns and increase the minimum possible net returns. Conversely, purchasing RP decreases the maximum possible net returns relative to not purchasing RP for the producer. With a planting window between 1 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 soybean and not purchase RP crop insurance. However, the highest

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MG II</th>
<th>MG III</th>
<th>MG IV</th>
<th>MG V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (b_0)</td>
<td>−5790.38</td>
<td>−3467.8</td>
<td>−2361.79</td>
<td>−4740.73</td>
</tr>
<tr>
<td>D (b_1)</td>
<td>127.04**</td>
<td>103.30**</td>
<td>87.43**</td>
<td>117.48**</td>
</tr>
<tr>
<td>D^2 (b_2)</td>
<td>−0.471**</td>
<td>−0.404**</td>
<td>−0.336**</td>
<td>−0.404**</td>
</tr>
<tr>
<td>Optimal date</td>
<td>24 May</td>
<td>16 May</td>
<td>13 May</td>
<td>22 May</td>
</tr>
<tr>
<td>90% confidence interval</td>
<td>20 Apr.–25 June</td>
<td>13 Apr.–16 June</td>
<td>7 Apr.–15 June</td>
<td>19 Apr.–19 June</td>
</tr>
<tr>
<td>Optimal yield, kg ha−1</td>
<td>3399.54</td>
<td>3569.01</td>
<td>3447.96</td>
<td>3535.39</td>
</tr>
<tr>
<td>Optimal net returns, US$ ha−1†</td>
<td>305.97</td>
<td>361.73</td>
<td>321.79</td>
<td>350.71</td>
</tr>
</tbody>
</table>

** Significant at the 0.01 level.
† Optimal net returns were calculated using the average price for soybean of US$0.33 kg−1 and production costs of US$816 ha−1.
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 RP coverage levels, MG III had the highest expected net returns (Table 3), although the returns decreased as RP coverage increased. As anticipated, the variability of net returns also decreased as RP coverage increased (Table 3).

When the planting window was widened from 1 to 31 May to be between 1 May and 15 June, the highest expected net returns and highest variability for those net returns were still found for MG III at all RP coverage levels (Table 3). A profit-maximizing, risk-neutral producer would still choose MG III soybean 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 occurred because more dates beyond the profit-maximizing ones were included in the distribution.

### Risk Analysis

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

The SERF was used to determine the preferred MG and RP management strategy by decision-makers with different levels of absolute risk aversion. Figure 3 shows the SERF ranking of the 16 management strategies for the 1 to 31 May planting window. The figure shows the risk premiums for all 16 management strategies for the 1 to 31 May planting window between 1 and 31 May, MG III with no RP was preferred by a risk-averse decision-maker. If a producer has a planting window between 1 and 31 May, MG III with no RP was preferred for $0 \leq \text{ARAC} \leq 0.0075$. Producers with more risk-averse preferences, as indicated by $0.0075 < \text{ARAC} \leq 0.03$, would prefer MG III with the purchase of RP coverage of 80%. The second most preferred combination was MG V without RP for $0 \leq \text{ARAC} \leq 0.009$; then, the producer would prefer MG V with the purchase of RP coverage of 80% for $0.009 < \text{ARAC} \leq 0.03$. Figure 4 shows the SERF ranking of the 16 management strategies for the 1 May to 15 June planting window. Similarly, MG III with no RP was preferred for $0 \leq \text{ARAC} \leq 0.0063$; then, producers would prefer MG III with the purchase of RP coverage of 80% for $0.0063 < \text{ARAC} \leq 0.03$.

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

### CONCLUSIONS

Planting date and cultivar maturity are important decisions that affect soybean production profitability, risk, and subsequent crop insurance choices for farmers in the southern United States. This study evaluated (i) the optimal planting date to maximize soybean net returns considering cultivar maturity, and (ii) the risk and expected net return tradeoffs among different soybean planting date windows, cultivar maturities, and crop insurance coverage options. Data were collected from a soybean planting date experiment for MGs II, III, IV, and V in Milan, TN, from 2008 to 2010. Soybean yield response as a function of planting date was estimated for each cultivar maturity. Net returns for the four MGs with four RP insurance coverage levels were simulated to determine the optimal maturity and coverage level that is preferred by risk-averse producers under two planting date windows. The results can assist producers in determining the optimal planting windows and crop insurance options for soybean production in Tennessee based on their risk preferences.
Fig. 3. Stochastic efficiency with respect to a function under a negative utility exponential utility function for soybean planted between 1 May and 31 May by maturity group (MG) and revenue protection (RP) coverage level.

Fig. 4. Stochastic efficiency with respect to a function under a negative utility exponential utility function for soybean planted between 1 May and 15 June by maturity group (MG) and revenue protection (RP) coverage level.
The profit-maximizing planting date for soybean in Tennessee ranged between 13 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 that there was no difference in the profit-maximizing planting date across MGs and that producers have a long period for planting in Tennessee, which has also been found for other southeastern states (Egli and Cornelius, 2009; Chen and Wiatrak, 2010). The SERF analysis showed that a risk-neutral to slightly risk-averse decision-maker would prefer MG III with no RP; however, as risk aversion increased, the preferred management strategy was MG III with 80% RP.

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