MARKETING & OUTLOOK BRIEFS
Department of Agricultural and Consumer Economics
University of Illinois at Urbana-Champaign

Early Prospects for 2009 Soybean Yields in Illinois, Indiana, and Iowa

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July 2, 2009

MOBR 09-02

INTRODUCTION

The USDA's first forecast of the potential size of the 2009 U.S. soybean crop was released on May 12 (USDA/WASDE, 2009). That forecast was based on: 1) acreage expected to be harvested for grain, which is a function of planting intentions revealed in the March 2009 *Prospective Plantings* report and the 5-year average planted to harvested acreage ratios by state, and 2) projected yield, which USDA generated based on a 1987-2007 regional trend analysis. The projected yield was 42.6 bushels per acre and the production forecast was 3.195 billion bushels. That forecast was unchanged in the June report.

Extended planting delays were experienced in a number of states, particularly in Illinois, Indiana, Kentucky, Missouri, and Tennessee. In contrast, planting progress was at a more normal pace in other large soybean producing states. Nationally, only 66 percent of the crop was planted as of May 31, 2009, compared to an average of 79 percent for the previous 5 years. While planting progress eventually accelerated, 4 percent of the crop was still unplanted as of June 28. The general lateness of planting and the large discrepancy in planting progress by region raises additional questions about the potential U.S. average soybean yield in 2009. In addition the USDA's June 30 *Acreage* report indicated that 77.483 million acres of soybeans were or will be planted in 2009. That is 1.459 million more than indicated in March and will alter production expectations.

The purpose of this brief is to evaluate 2009 yield potential for soybeans in Illinois, Indiana, and Iowa using a previously developed crop weather model that estimates the impact of technology (trend), state average monthly weather variables, and portion of the crop planted late on state average yield (Irwin, Good, and Tannura, 2008). The model is first re-estimated to better capture the influence of late planting and then used to analyze yield prospects in each of the three states for 2009. Then, yield projections are made based on actual weather through June, the portion of the crop planted after May 30th, and the probability that summer weather conditions reflect the actual distribution of summer conditions from 1960 through 2008. This is referred to as the "average" forecast. Projections are also made based on "poor" and "good" summer weather conditions. These three scenario forecasts are then compared to the trend yield for 2009 and some preliminary thoughts of yield potential in each of the three states are presented. Finally, some discussion of the potential U.S. average soybean yield and soybean production in 2009 is provided.

PLANTING DATES AND YIELD

Among the many factors, other than weather, that can influence soybean yields, planting date has been demonstrated as important (Egli, 2008). There are, however, two aspects of planting date that may be important for yields. One is the trend toward earlier planting that is thought to contribute to the overall trend increase in yields. Figure 1 illustrates the trend toward earlier planting of soybeans in Illinois. Compared to 1965, for example, soybean planting in Illinois in 2005 was started and completed about two weeks earlier.[1]

The second aspect of the planting date influence on yields is the timeliness of planting in a given year. Agronomic research reveals that "late" planting in a given year generally results in lower soybean yields than timely planting (Pecinovsky and Benson, 2001; De Bruin and Pederson, 2008; Nafziger, 2009). Figure 2 is representative of results from agronomic experiments investigating the effect of planting date on soybean yields. These results suggest that conclusions about the influence of planting date on yields have changed over time. The 2001 study by Pecinovsky and Benson, for example, found soybean yields in central Iowa not to be substantially different for planting dates ranging from late April to early June. The 2008 study by De Bruin and Pederson, however, found yields to decline at an accelerating rate for planting dates after late April. For a concise discussion of these results see Nafziger, 2009. These recent results imply that planting date has a much more substantial influence on yield than previously thought.

Planting date results from agronomic experiments are widely used as a guide to planting decisions by farmers. This is sensible for individual farmers in a given year because the experiments carefully isolate planting date impacts by holding other production factors constant. However, experimental results do not necessarily provide good estimates of actual planting date impacts for large areas, such as states or regions. The first reason is that planting in any given year generally is spread over several weeks, with some acres planted in a timely fashion and some planted late. The second reason is that spring and summer growing season weather varies substantially from year-to-year. Nielsen (2008) notes that yield loss estimates from agronomic experiments are relative to the maximum yield possible in a given year. The variation in maximum yield due to variation in growing season weather can easily swamp the impact of planting delays.

An alternative approach is to partition the effect of planting date on state average yields over time using a crop weather model. This is also challenging due to uncertainties about the specification of planting date variables, and consequently, few attempts have been made to estimate the impact of planting date on state average yields.

STATE LEVEL PLANTING PROGRESS

The U.S. Department of Agriculture (USDA) provides a weekly assessment of cumulative state soybean planting progress, expressed as the percentage of the crop planted, in the *Crop Progress* report. Planting progress data for 1979 through 2009 are available at the USDA's Quick Stats web site.[2] For years before 1979, planting progress information is available in the *Weekly Weather and Crop Reports* from individual states. Since 1979, weekly planting progress has been reported for all states as of the week ended on Sunday. Prior to that, the week-ending date was Monday for Illinois and Iowa. The week ending date for Indiana was Saturday for

[1] See Irwin, Good, and Tannura (2008) for further information on trends in planting dates since 1960 for Illinois, Indiana, and Iowa.

[2] See http://www.nass.usda.gov/QuickStats.

1960-1966, Friday for 1967-1976, and Sunday for 1977-1978.

Measuring the magnitude of late planting is complicated by three issues. The first is the changing yield penalty as planting dates become progressively later. Based on the response curves presented in Figure 2, separate variables representing the percentage of the crop planted in each interval could be specified. This would likely lead to over-parameterized models and imprecise parameter estimates. Estimation would be further complicated by the positive correlation between such variables. The second issue is that the definition of "lateness" probably has changed over the sample period. It is reasonable to assume that the trend towards earlier planting dates goes hand-in-hand with changing experimental evidence on optimal planting dates. The third issue is that planting date impacts are already represented to some degree in previous crop weather models via May precipitation variables.

Some of these issues were addressed in the crop weather models developed a year ago by Irwin, Good, and Tannura (2008). A two-pronged approach was adopted to represent late plantings in each year of the sample. The first part of the approach was to specify May precipitation in quadratic form. This would allow the relationship between May precipitation and soybean yields to exhibit declining yields if too little or too much precipitation is received. The second part of the approach was to include a variable in the crop weather models to represent soybeans planted towards the end of the windows represented in Figures 2.

Irwin, Good, and Tannura (2008) consulted *Illinois Agronomy Handbooks* going back to 1968 with regard to changing agronomic recommendations for soybean planting dates. There was little change in recommendations for soybeans, with the main thrust that farmers should complete soybean plantings in the month of May. Pecinovsky and Benson (2001) report results of soybean planting date studies in Iowa from 1976 through 2001. Planting date recommendations from 1976-1980 are about a week later than recommendations for 1992-2001, but the main finding is that sharp reductions in soybean yields are observed starting in early June. Based on this information, the late planting variable was defined as the percentage planted after June 10th.

REVISED CROP WEATHER MODELS

The crop weather models presented by Irwin, Good, and Tannura (2008) were re-estimated using state-average soybean yields in Illinois, Indiana, and Iowa over 1960-2008.[3] In these earlier models, a linear time trend variable was used as a proxy for technology. Weather variables included total pre-season precipitation (September-April), May through August monthly precipitation, and June through August monthly average temperature. Pre-season precipitation and all temperature variables were included in linear form, while May through August precipitation was included in quadratic form. The late planting variable discussed in the previous section was also included in linear form.

Those models explained about 90 percent of the annual variation in state average soybeans yields from 1960 through 2007. However, the late planting and May precipitation variables were highly correlated, which created estimation problems for both variables. Specifically, May precipitation was not a statistically significant variable in any of the states and the late planting variable was only significant in Indiana. In addition, the June temperature variable was not statistically significant in any state and preseason precipitation was only significant in Iowa.

[3] See Tannura, Irwin, and Good (2008a) for a detailed discussion of the specification and estimation of crop weather models.

Several changes were made to the crop-weather model in an effort to improve yield forecasts while at the same time maintaining a relatively simple specification. The revised model retains the same trend variable, but May precipitation is dropped from the model in order to address problems created by the correlation between lateness of planting and May precipitation. The preseason precipitation variable is also entered in quadratic form. May and June temperature variables are deleted from the model as well.

The definition of late planting was also changed to the percentage planted after June 10th over 1960-1985 and after May 30th over 1986-2008. This change was done for two reasons. First, this is consistent with the actual trend in soybean planting dates over time. Second, this is consistent with more recent planting trial results that show larger benefits to earlier planting of soybeans.[4]

The late planting variable for each state is plotted in Figure 3 over 1960-2009. There is almost no trend in any of the late planting variables, indicating that the specification of "lateness" remains stable over time. The charts also indicate that, except for Indiana, the percentage of soybeans planted late is relatively low in most years and a handful of years have very high values. The historically large magnitude of planting delays in the eastern Corn Belt during 2009 is highlighted in the plots for Illinois and Indiana. The 69 percent of soybeans planted after May 30th in Illinois was only exceeded in three other years, 1974, 1995, and 1996. The 54 percent of soybeans planted after May 30th in Indiana was one of the ten largest readings over 1960-2008. With only 11 percent planted after May 30th this year, the level of late planting in Iowa was actually below average.

The crop weather models estimated over 1960-2008 are presented in Table 1. In the revised models, each one percent of the crop planted late reduces the state average soybean yield by 0.04 bushels in Illinois and 0.07 bushels in Indiana and Iowa. The late planting coefficient estimates in the revised model are similar to those of the previous model, but are now statistically significant in all three states, consistent with experimental trials that show substantial penalties for late planting in all three states. In addition, the magnitude of late planting effects implied by the coefficients indicates that step-wise planting trial results, such as those found in Figure 2, are approximated reasonably well. For example, assume that 50% of the Iowa soybean crop is planted from May 15th-30th, and 50% from June 1st-June 15th. The yield penalty estimated by the crop weather model for Iowa would be 3.4 bushels, compared to a yield penalty of 4.9 bushels based on the 2008 planting trial results in Figure 2.

The effect of other weather variables is similar to those estimated in the previous version of the model.[5] The estimated impact of each variable on soybean yield in the three states is presented in Figure 4. The impacts are plotted for the historical range of each variable across the three states and

[4] The late planting variable was also considered in quadratic form, with no improvement in model performance.

[5] The possibility of a change in the trend rate of growth in soybean yield was investigated for the revised models. Some argue that soybean trend yields reached a plateau in the last decade. Unknown breakpoint tests do not provide evidence of a statistically significant change in trend in any of the three states during the sample period. Additional tests that restrict the trend breakpoint to years in the mid- to late-1990s indicate a small and insignificant decrease in trend for Illinois (about 0.03 bushels per year) and a small and significant decrease in trend for Indiana (about 0.05 bushels per year) and Iowa (about 0.08 bushels per year).

the X's indicate the average level of the variable over 1960-2008.[6]

MODEL PROJECTIONS FOR 2009

As a starting point, 2009 trend yields for each state are calculated. This calculation is not as straightforward as it first appears. Conventionally, trend yield is calculated from the best linear fit of historical actual yields on a time trend variable (1,2,3,…). For example, the best linear fit of actual yields in Illinois from 1960 through 2008 results in a trend calculation for 2009 of 47.0 bushels. This methodology results in a slight underestimate of trend yield due to the asymmetric effect of weather on actual yields. That is, poor weather reduces yields more than good weather improves yields so that the impact of technology (trend) is underestimated due to sharp reductions in yield from "poor weather" years, such as 1974, 1983, 1988, and 1993 (Swanson and Nyankori, 1979; Tannura, Irwin, and Good, 2008).

An alternative approach to calculating trend yield for 2009 is to impose on the crop weather model the assumption of average weather over the past 49 years along with the average portion of the crop planted late over that period. That approach results in a calculation of 48.8 bushels for Illinois in 2009. But, this calculation overstates trend yield, again due to the asymmetric effect of weather on yields. That is, the assumption of average weather does not accurately reflect the large negative yield effects of poor weather relative to the smaller positive effects of good weather.

A third approach, and the one adopted here, is based on the assumption that the actual distributions of weather conditions and late planting over the past 49 years are representative of the distributions expected for 2009. That is, the model results are computed for each of the 49 years in the data series, assuming 2009 production technology, and the model results are averaged to represent the trend yield for 2009. That calculation is 47.4 bushels for Illinois, 47.4 bushels for Indiana, and 50.0 bushels for Iowa. These calculations can be viewed as the most likely yield outcomes (in terms of 2009 technology) if the conditions in each year from 1960 through 2008 had an equal probability of occurring in 2009.

Yield forecasts also are made for 2009 using the crop weather model under poor and good weather scenarios. All three scenarios—average, poor, and good—incorporate actual precipitation from September 2008 through April 2009, the percent of the crop planted late in each state, and actual June 2009 precipitation, but reflect different weather scenarios for July and August.[7] Average weather is reflected by computing model yield predictions for actual July-August weather conditions in each year from 1960 through 2008 and averaging the results. This is different than applying the model assuming average July-August weather conditions of the past 49 years. The latter calculation would overstate yield prospects for reasons

[6] The response curve for preseason precipitation in Iowa has a much sharper decline than the other two states. This is simply an artifact of plotting the response for the range of preseason precipitation across the three states. The highest level of preseason precipitation in Iowa, 24.30 inches, is actually much lower than the highest level of preseason precipitation in Illinois and Indiana. This is also reflected in the much lower level of average preseason precipitation for Iowa.

[7] The June weather observations are collected from preliminary data published by the Midwest Regional Climate Center (http://mrcc.sws.uiuc.edu/prod_serv/prodserv.htm). The data do not become official for several months until they are finalized by the Climate Prediction Center. Since the MRCC data only utilizes real-time weather observations, changes in the values are probable once additional weather observations (non real-time) are collected and included for each state.

discussed above relative to trend yield calculations.

The poor weather scenario reflects the average of the model yield predictions for the ten most unfavorable July-August conditions from 1960 through 2008. The good weather scenario reflects the average of the model yield predictions for the ten most favorable July-August weather conditions from 1960 through 2008. Note that favorable and unfavorable weather years in the poor and good scenarios are not directly identified based on actual weather conditions. Instead, those years are identified by applying the model to each year from 1960 through 2008 assuming 2009 production technology, actual weather through June 2009, and the portion of the crop planted late in 2009. The 10 lowest yield forecasts are averaged to produce the poor weather forecast and the 10 highest yield forecasts are averaged to produce the good weather forecast. This is akin to using the model projections for each year as a weather index (Doll, 1967).

Yield forecasts are presented in Table 2. The first point of importance is that trend yield calculations for each state are consistent with the previous 3-year average yield in each state (Figure 5), suggesting that market participants may have a reasonable starting point in forming expectations about yield potential in 2009 if data for recent years is considered.

The second point is that late planting in Illinois is likely to have reduced yield potential to below trend value unless summer weather is favorable.. The average weather scenario (as defined earlier) results in yield forecasts 0.9 bushels below trend in Illinois.

There is, of course, great interest in the specific impact of planting progress on soybeans yields in 2009. Estimated impacts illustrated in Figure 6 are relatively large (and negative) for Illinois and Indiana due to the extreme lateness of planting. There is a small positive impact from very timely planting in Iowa. It should be noted that the model specification makes these impacts permanent regardless of summer weather. Yields would be expected to be lower in Illinois and Indiana under all three weather scenarios than would be experienced had planting been more timely. The actual level of preseason precipitation this year is expected to have a positive impact on yield potential, particularly in Iowa. Similarly, the estimated level of June precipitation is expected to have a positive impact on yield potential in all three states.

The third point is that weather conditions to date and two of the three alternative summer weather scenarios considered point to a high average yield in Iowa. The average summer weather scenario results in a yield forecast 1.9 bushels above trend value and 2.4 bushels above the average yield of the past three years. Only a poor summer weather scenario would be expected to reduce the state average yield below trend value.

At this juncture, we anticipate that the 2009 average yield in Illinois will likely be below trend value, but slightly above the average of the past three years (46.2 bushels). For Indiana, 2009 yield prospects appear to be near the trend value and the average of the past tree years (47 bushels). Conversely, it appears there is a reasonably high probability that the Iowa state average yield will be above both trend and the average of the past three years (49.5 bushels).

What are the implications for U.S. average yield prospects? It appears that Illinois and Iowa yield prospects reflect the extremes of yield potential relative to trend in 2009. Planting delays of lesser severity than in Illinois (as revealed in weekly estimates of the percent of the crop emerged) were experienced in Indiana, Kentucky, Missouri, and Tennessee. Conversely, planting was timely in most other states.

In assessing U.S. yield prospects for soybeans, the starting point is the appropriate trend yield calculation in 2009. Ideally, trend value could be calculated for each state in the same fashion as was done here for the three states (equal chances that 2009 summer weather would replicate one of the past 49 years) and the results weighted to form a national trend. Instead, most analysts use a trend of actual yields over a specific time period to calculate trend yield. Such a calculation generally underestimates trend yield due to the asymmetry of weather impacts as described earlier. In addition, such calculations can be biased by using an inappropriate time period. Some use a shorter time period than the 49 years we use here in order to capture a plateau in soybean trend yields thought to be occurring in more recent years. Based on application of the crop weather models for Illinois, Indiana, and Iowa, we see evidence of, at most, only a very small decrease in trend in recent years (see footnote 5). The trend of actual yields over a recent short time period may actually understate trend for 2009.

A simple linear trend calculation for the U.S. soybeans yield in 2009 based on actual yields for the period 1960 through 2008 is 41.6 bushels. Lacking any better information, we adjusted this simple linear trend calculation for the U.S. based on the observed bias in the simple linear trend estimates for Illinois and Iowa.[8] Simple linear trend coefficients for these states were on average 0.02 bushels per year smaller than the corresponding estimates from the crop weather models. We assume that the true bias at the national level would only be half of this value because the impact of state level weather extremes would be dampened at the national level. This results in a 0.6 bushel upward adjustment (0.01 bushels/year X 50 years) in the U.S. trend yield to 42.2 bushels.

Since crop weather forecasts have only been developed for Illinois, Indiana, and Iowa, we follow a revised version of the procedure developed by Irwin, Good, and Tannura (2008) for projecting U.S. yields under the three weather scenarios. The first step is to calculate an acreage-weighted average of the three state forecasts, which is shown in Table 2. Irwin, Good, and Tannura (2008) used a simple average of the three state forecasts. The second step is to adjust the three-state average by the average ratio of the three-state weighted-average yield to national average yield over the last 10 years. Since Illinois, Indiana, and Iowa typically represent nearly 40 percent of U.S. production this ratio is fairly stable and averaged 1.158 over the last decade. As an example of the adjustment procedure consider the scenario of average summer weather. The weighted-average of the three state yield forecasts is 48.9 bushels. Divided by 1.158, that average projects to a U.S. average yield of 42.2 bushels, equal to the trend yield for 2009.

The size of the 2009 crop will also depend on the magnitude of harvested acreage. Based on the USDA's June *Acreage* report, producers intend to harvest about 76.6 million acres of soybeans in 2009. The yield forecast based on average summer weather conditions points to a crop of 3.231 billion bushels.

CONCLUDING THOUGHTS

A yield forecast that reflected the current forecast of summer weather also could have been included in the analysis. That was not done because the outlook for August is not particularly reliable. The current National Weather Service outlook for July suggests varied conditions across the three states.

We suggest caution in the application of the specific forecasts from the crop weather model. The forecast errors of previously

[8] Indiana is excluded due to the unusual result that the simple linear trend estimate actually is higher than the trend estimate from the crop weather model.

developed models were relatively large and that is likely the case for the current specification. Standard errors of the forecasts at this point in the growing season could easily exceed 3 bushels per acre. Nonetheless, combined with informed judgment and other information, such as USDA weekly reports of crop conditions, the models can be useful in forming production expectations.

We will continue to update the 2009 soybean yield and production forecasts as the season progresses. Actual July precipitation levels and forecasts for August weather will be used in the crop weather models to update forecasts in early August. In addition, crop condition reports will be used to augment model yield results. A similar update will be provided in early September.

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Table 1. Regression Estimates of Crop Weather Models for Soybean Yield in Illinois, Indiana, and Iowa, 1960 - 2008

	Coefficient Estimates					
Independent Variable or Statistic	**Illinois**		**Indiana**		**Iowa**	
Constant	28.31		10.87		29.10	
	(1.15)		(0.49)		(1.21)	
Annual Time Trend	0.42	***	0.43	***	0.49	***
	(16.87)		(16.00)		(14.25)	
Late Planting	-0.04	**	-0.07	***	-0.07	**
	-(2.15)		-(4.29)		-(2.11)	
Preseason Precipitation	1.84	*	0.67		2.12	*
	(1.74)		(0.64)		(1.73)	
Preseason Precipitation^2	-0.04		-0.01		-0.06	
	-(1.57)		-(0.46)		-(1.54)	
June Precipitation	0.96		4.64	***	2.01	
	(0.76)		(4.11)		(1.36)	
June Precipitation^2	-0.06		-0.45	**	-0.17	
	-(0.47)		-(3.47)		-(1.21)	
July Precipitation	3.86	**	3.90	***	3.19	***
	(2.12)		(3.87)		(3.18)	
July Precipitation^2	-0.33		-0.35	***	-0.32	**
	-(1.63)		-(3.60)		-(3.29)	
August Precipitation	1.84		3.96	**	2.99	*
	(1.10)		(2.35)		(2.85)	
August Precipitation^2	-0.11		-0.38	*	-0.21	**
	-(0.54)		-(1.82)		-(2.08)	
July Temperature	-0.01		-0.07		-0.37	
	-(0.04)		-(0.33)		-(1.52)	
August Temperature	-0.55	**	-0.25		-0.19	
	-(3.40)		-(1.56)		-(0.95)	
R^2	0.91		0.93		0.88	
Standard Error (bu./acre)	2.30		2.22		3.08	
Regression F-statistic	31.67	***	41.36	***	21.61	***

Note: The figures in parantheses are t-statistics. One, two, and three stars denote statistical significance at the 10%, 5%, and 1% levels, respectively. Monthly precipitation variables are stated in inches and monthly temperature variables are stated in degrees Farenheit. Preseason precipitation is the sum of precipitation over September (previous crop year) through March (current crop year). Late planting is measured as the % planted after June 10th from 1960-1985 and after May 30th from 1986-2008.

Table 2. Alternative Forecasts of 2009 Soybean Yield in Illinois, Indiana, Iowa, and 2009 U.S. Soybean Yield and Production

		June-August Weather		
	Trend	Average	Poor	Good
Panel A. State Yield Forecasts				
Illinois (bu./acre)	47.4	46.5	43.0	49.6
Indiana (bu./acre)	47.4	47.4	44.7	49.7
Iowa (bu./acre)	50.0	51.9	48.2	54.9
3-State Average (bu./acre)	NA	48.9	45.5	51.8
Panel B. U.S. Forecasts				
Yield (bu./acre)	42.2	42.2	39.2	44.7
Production (mil.bu.)	3,231	3,231	3,004	3,421

Notes: NA denotes 'not applicable.' See the text for a detailed explanation of each state yield forecast. The 3-state average forecasts are weighted by planted acreage for each state as reported in USDA's June 2009 *Acreage* report. U.S. production forecasts for 2009 assume 77.5 million planted and 76.6 million harvested acres, respectively. These figures are also drawn from USDA's June 2009 *Acreage* report.

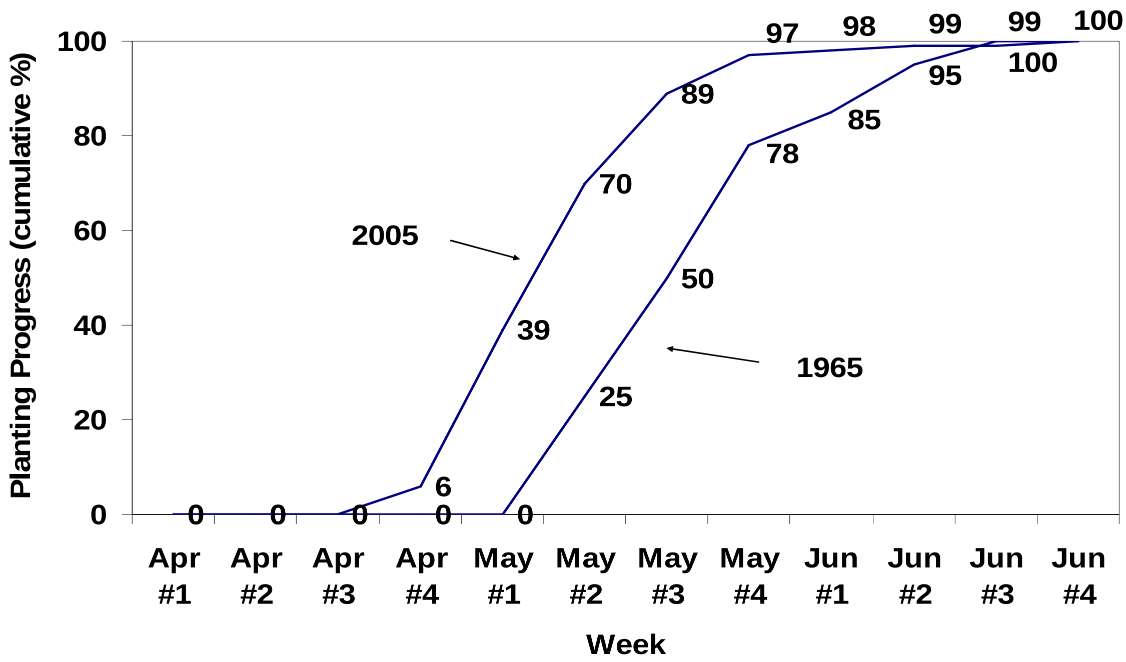
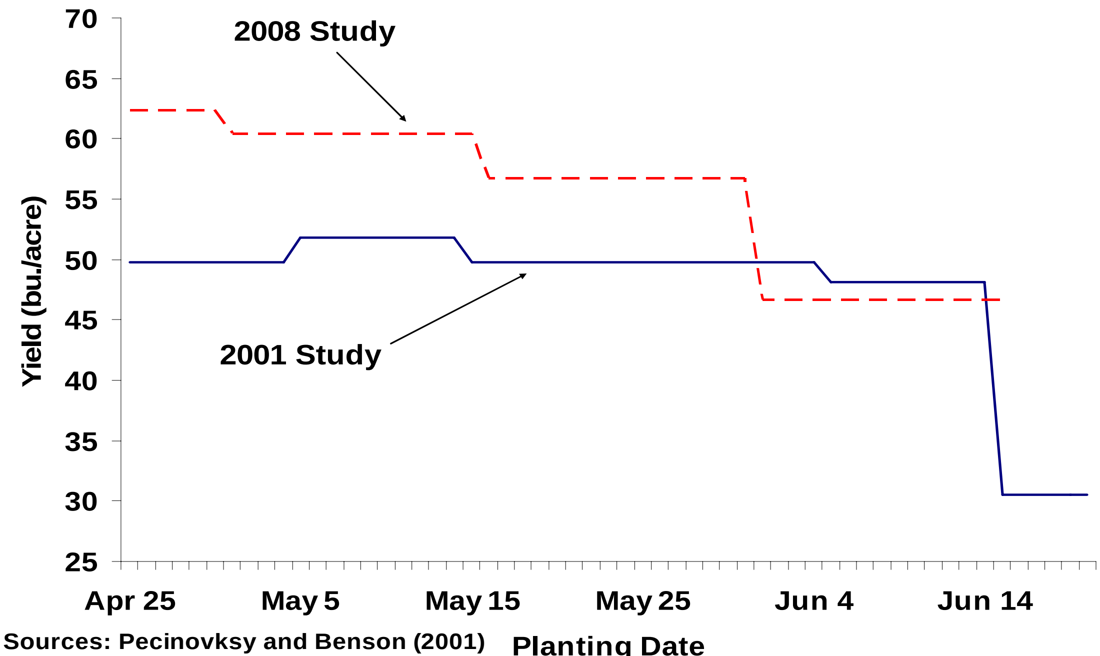


Figure 1. Comparison of Illinois Soybean Planting Progress in 1965 and 2005



Sources: Pecinovksy and Benson (2001)
De Bruin and Pederson (2008)

Figure 2. Response of Soybean Yield in Iowa to Planting Date

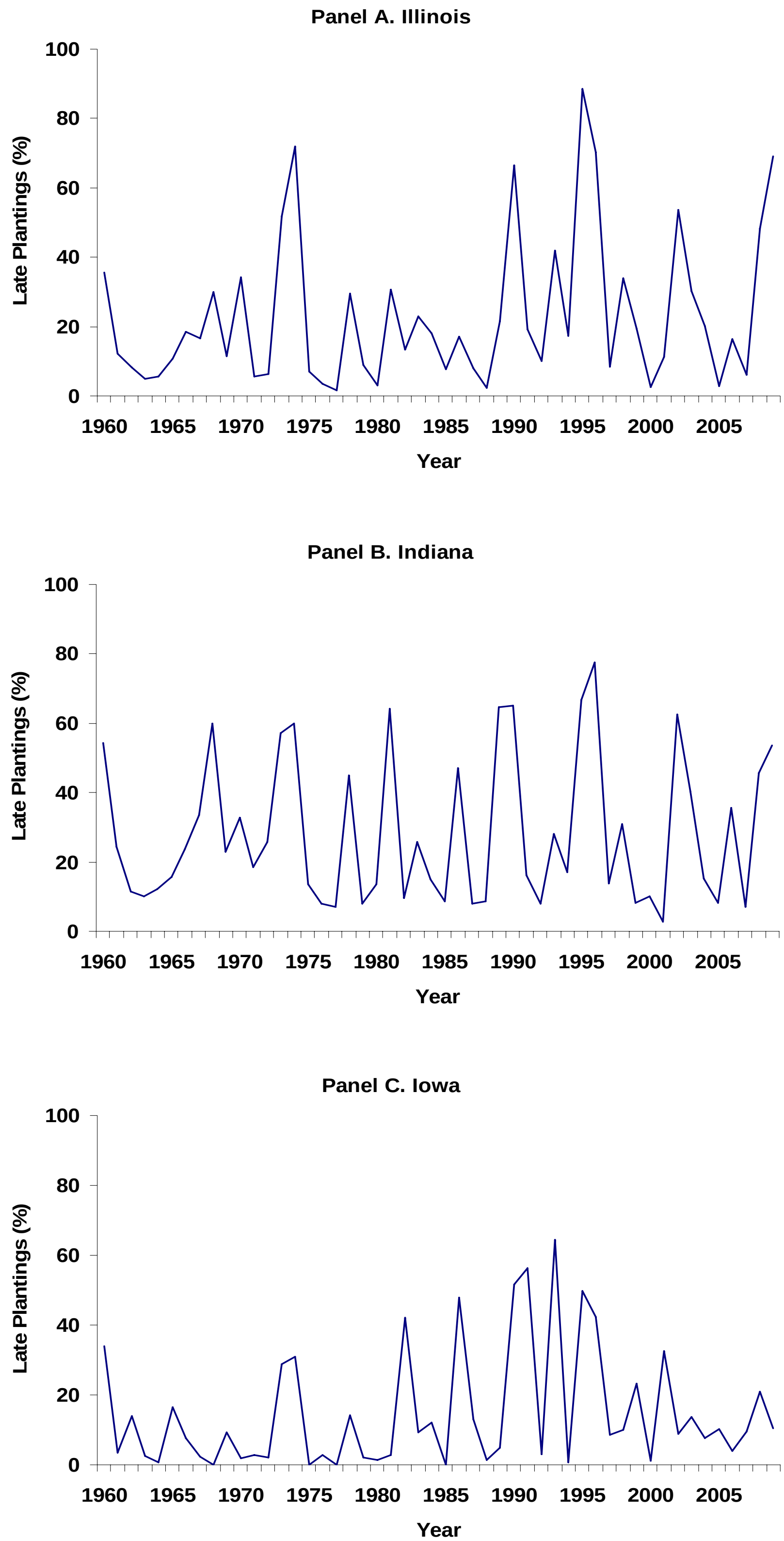


Figure 3. Proportion of Soybeans Planted after June 10th from 1960 - 1985 and after May 30th from 1986 - 2009 in Illinois, Indiana, and Iowa

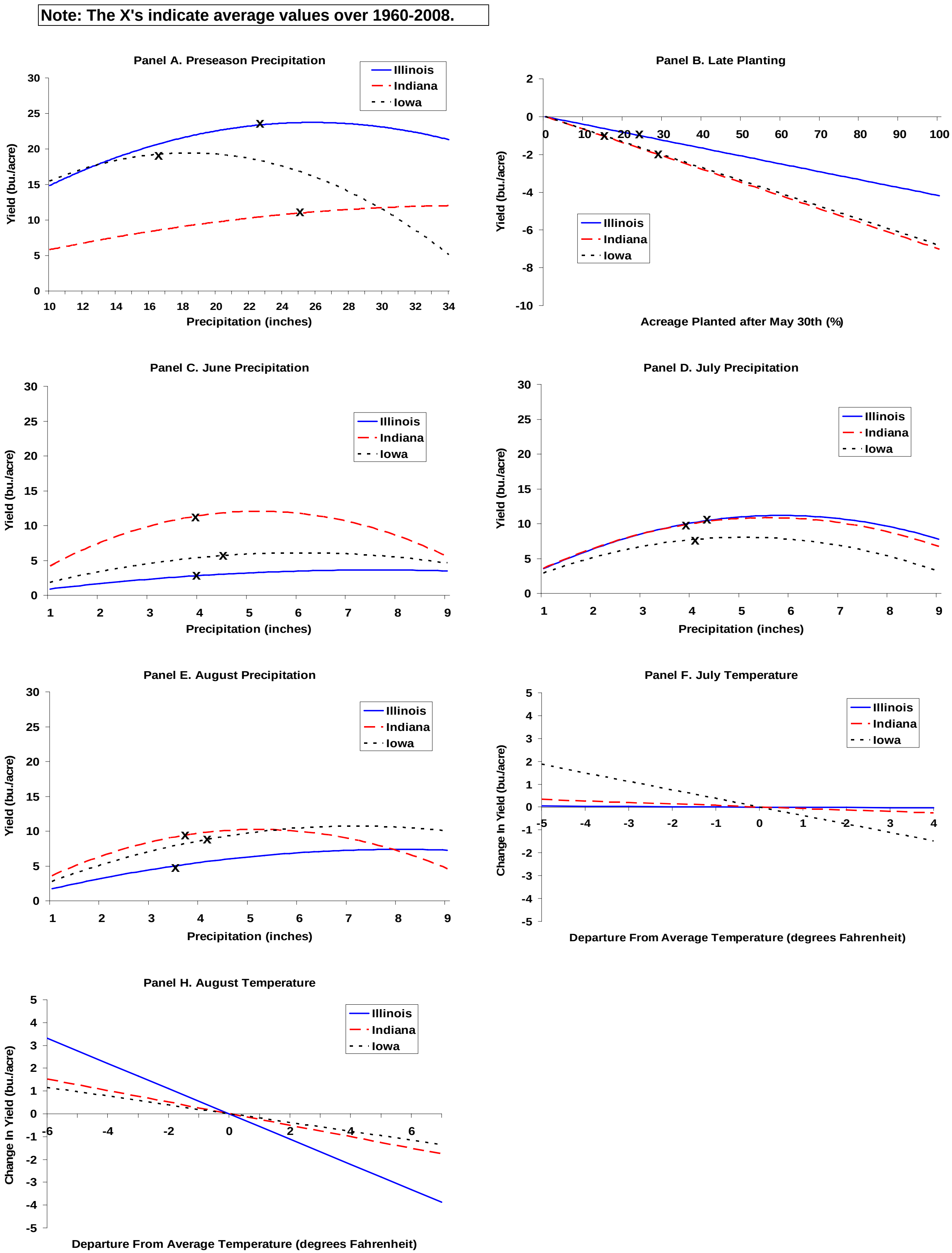


Figure 4. Estimated Impacts of Weather and Late Planting Variables on Soybean Yield in Illinois, Indiana, and Iowa, 1960-2008

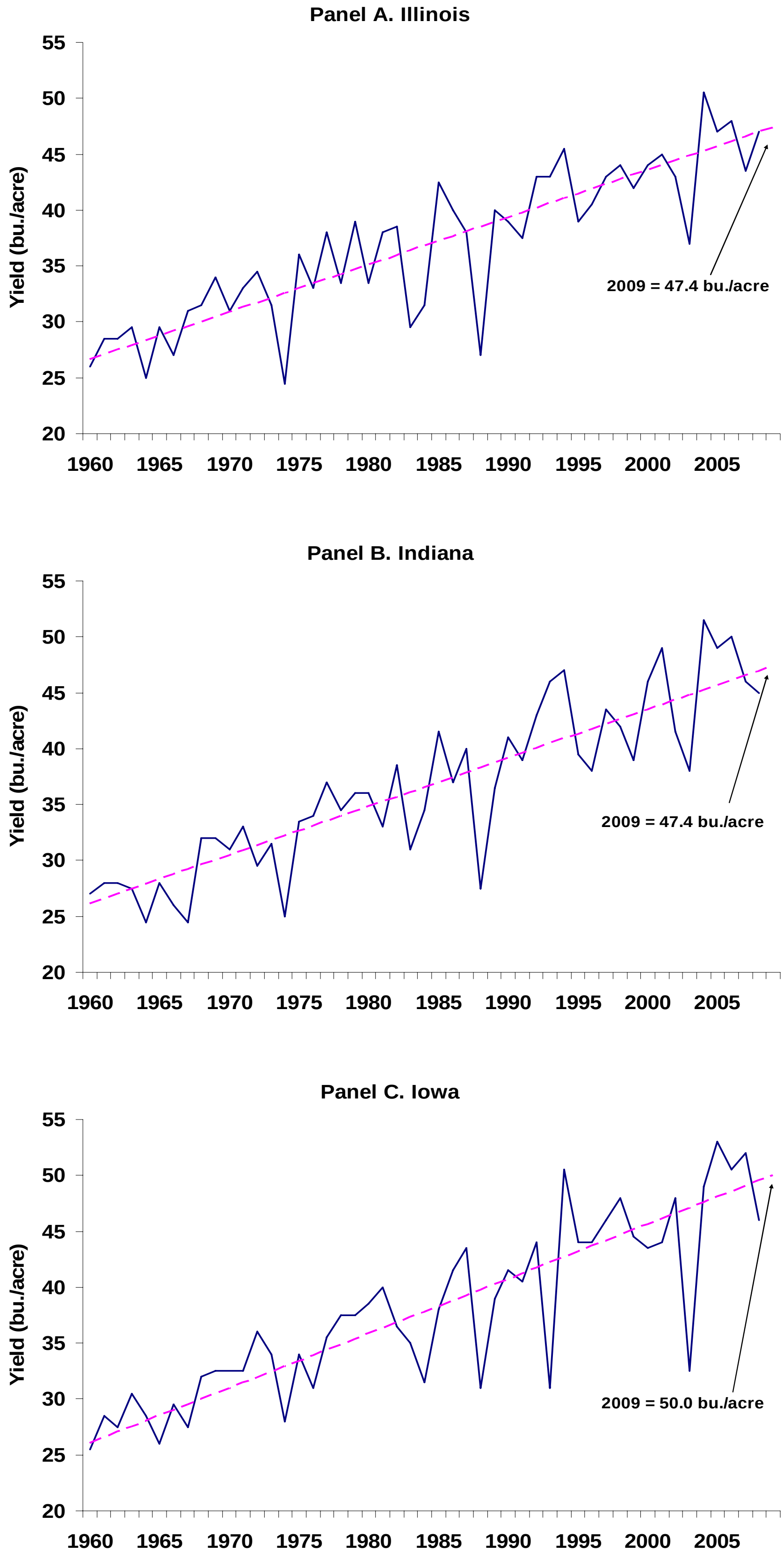


Figure 5. Actual and Trend Soybean Yield in Illinois, Indiana, and Iowa, 1960-2008

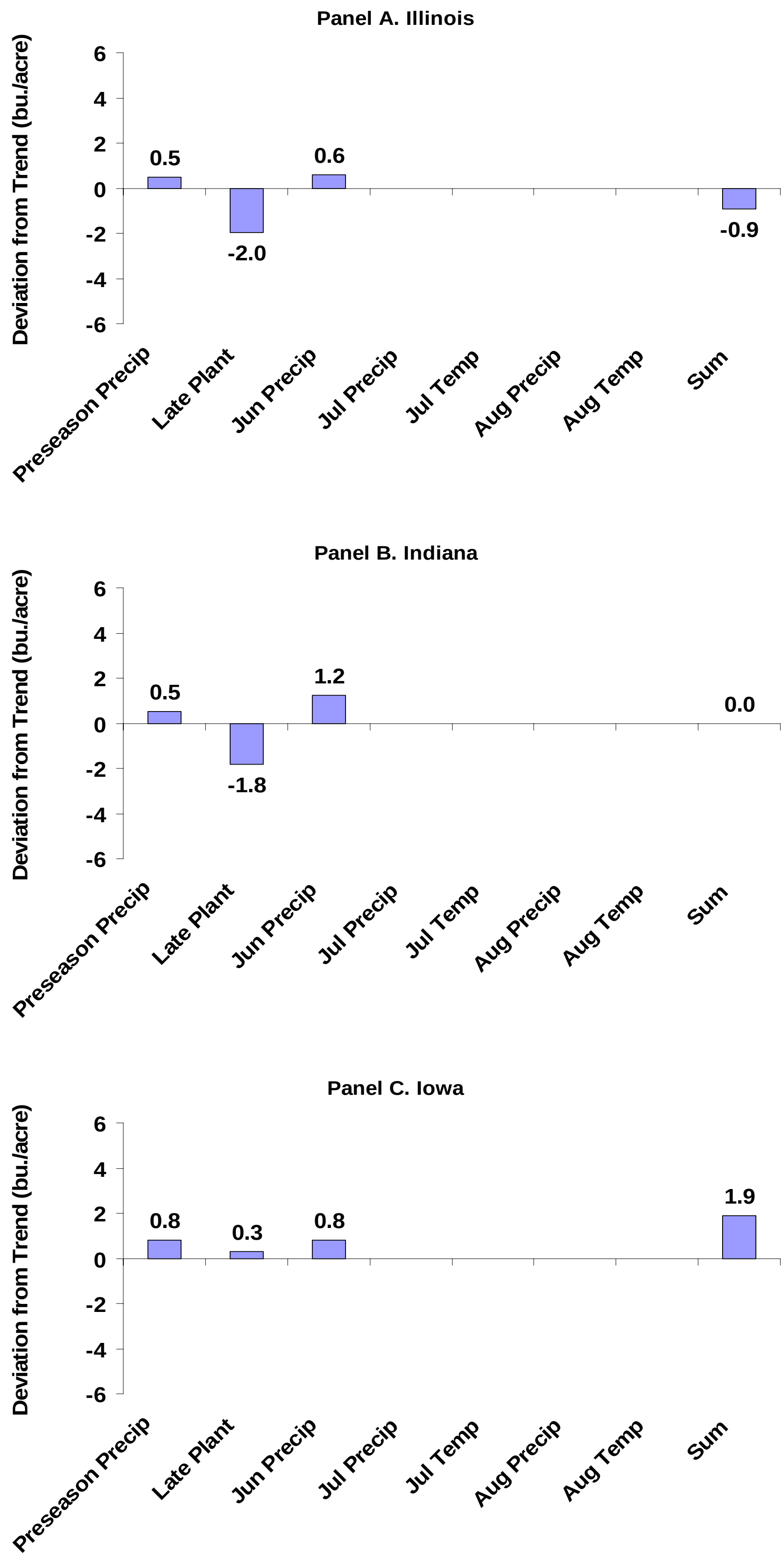


Figure 6. Estimated Impact of Monthly Weather and Late Planting Variables on Deviation from Trend Soybean Yield in Illinois, Indiana, and Iowa in 2009