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Resources needed for record-breaking soybean yields
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In 2006, the soybean industry was astounded when Kip Cullers, a farmer in southwest Missouri reported yields of 139 bushels per acre in the Missouri Soybean Association yield contest. These amazing yields were shattered in 2007 when Mr. Cullers reported yields of 155 bushels per acre. Previous to Mr. Cullers' reports, the record yield was 118 bushels per acre set in small-plot research by Dr. Roy Flannery in 1983 at Rutgers University in New Jersey.

The unprecedented yields from Mr. Cullers' farm have been met with an equal mix of excitement and skepticism. Crop scientists have generally concluded that the theoretical yield potential of soybean in the absence of drought stress was approximately 110 to 120 bushels per acre (Sinclair, 2004; Specht et al., 1999).

Theoretical yield potentials for soybean are based upon relationships of:

- the amount of crop mass that can be accumulated for each unit of light energy that the crop intercepts,
- the total amount of light that the crop can intercept during a growing season,
- how long during seed development the crop can maintain these high rates of crop growth,
- the availability of nutrients, particularly nitrogen, to meet demands of growing protein-rich seeds, and
- the amount of seed that the crop produces from the total above-ground plant weight (the harvest index, HI)

During the 2008 growing season, Mr. Cullers allowed me access to his contest soybean field. Although yields for the 2008 season from Mr. Cullers are not available as I write this report, I can describe my observations and measurements made during the season. I established small plots in his field where three varieties that ranged from a maturity group 4.7 to a 5.9. Measurements I made were aimed at documenting the amount of light energy intercepted by the crop, how efficiently that light energy was used for crop growth (weight), the rate and duration of seed growth during the season, and changes in leaf nitrogen concentration that occurred during seed growth.

Mr. Cullers' crop was completely canopied 40 days after emergence, and efficiency of light energy use for crop growth was high but similar to what others have reported. Once the crop began flowering, it was irrigated (-0.25 inch) most days when temperature was above 95 F. Leaf samples taken beginning at full bloom and extending throughout seed fill showed a gradual decrease in shoot nitrogen concentration (Figure 1). Of particular note was that at physiological maturity (R7), there was a near full canopy of green leaves (Figure 2) that had nitrogen concentrations of around 3% (Figure 1).
Measurements made during 2008 were then used to predict theoretical yield potential for the 2007 and 2008 seasons using a crop growth model (Sinclair et al., 2003). The model uses daily measurements of temperature and light energy along with values for how efficiently light is used by the crop for growth and how quickly seeds grow.

The predicted yields from the growth model were between 80 and 90 bushels per acre. Although most farmers would be pleased to have yields in this range (and some do), these yields are a far cry from the yields reported in Mr. Cullers' contest fields.

A major assumption of the growth model is that the amount of nitrogen that the crop can fix from the atmosphere plus the amount of nitrogen that the crop can take up from the soil is insufficient to meet the amount of nitrogen that the seed accumulates. In the model, this causes the leaves to export nitrogen to the seed, and the decrease in leaf nitrogen results in decreased crop growth and early senescence. This assumption, however, does not agree with the measurements of leaf nitrogen as the crop reaches R7 (Figure 1) or the canopy of green leaves at maturity (Figures 2 and 3).

When the model was 'reprogrammed' so that the crop had plentiful nitrogen throughout the season, predicted yields ranged from 134 to 160 bushels per acre. This range of yields is similar to those reported from Mr. Cullers' contest fields.

If the extraordinary yields from Mr. Cullers' are due to increased nitrogen availability, the question becomes 'How is enough nitrogen applied or fixed by soybean to prevent leaves from exporting their nitrogen to seeds?' Mr. Cullers routinely applies chicken litter to his soybean fields, and 3 tons per acre of litter would supply about 180 pounds of N per acre. Mr. Cullers also uses his center pivot as a fertigation system, and the frequent irrigations during the season provide an opportunity to apply large amounts of nitrogen through many applications. Finally, Mr. Cullers' soybean plants are well nodulated and are apparently fixing nitrogen. A combination of these factors may provide sufficient nitrogen for the crop to obtain these extraordinary yields.

References


Figure 1. Leaf nitrogen concentration versus days from the beginning of linear seed fill. Data were from three varieties in 2008 from Kip Cullers’ contest field. Arrows indicate that plants were at, or past, physiological maturity (R7) when leaf samples were taken.

Figure 2. Photograph from Kip Cullers’ contest field in 2008. The photograph was taken as the crop approached physiological maturity. Note the large number of green leaves and pods approaching mature color.
Figure 3. Photograph from Kip Cullers' 2007 crop. At this time, the crop was past physiological maturity. Note that all pods are mature color and that there is a near full canopy of green leaves.