Transferring Soybean Production Technology to Specific Sites Using Decision Support Systems

Summary of Work Completed, Results, and Implications

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About this report

United Soybean Board Project #7211, “Transferring Soybean Production Technology to Specific Sites Using Decision Support Systems,” was recently concluded after two successful years of intensive fieldwork, research, and development.

A “proof of concept” soybean decision support system (DSS) was the focus for our research and development activities. Our team investigated ways to integrate research information, such as weather data and soil characteristics, into DSS tools in order to facilitate management of specific soybean fields. Working directly with farmers and industry consultants, we evaluated this approach in three areas: for acceptance by the soybean industry, for integration of new research information, and for routine use by soybean farmers throughout the USA.

The ultimate goal of our work is the development of a sustainable process for soybean technology transfer—putting information learned in research into practice in the field.

This summary report provides an overview of work completed, researchers’ findings, and significance for soybean producers and for further study. It is divided into three sections, one representing each project objective.

Researchers in eight states participated in the studies summarized here; please see the final page of this document for their names and affiliations.

Printed copies of this report are available from the United Soybean Board. The report is also available on the World Wide Web, with other material related to similar projects, at http://www.agen.ufl.edu/~jjones/croplab/.

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Image produced by combine-mounted yield monitor, showing variability of soybean yield in a field in North Carolina
Decision Support System Evaluation

Evaluate a new soybean decision support system (DSS) for the accuracy and value of information provided to users.

Soybean producers' acceptance of crop model-based decision support systems depends on system availability, ease of use, reliability, and the value of information provided to users.

Researchers designed and produced a prototype DSS tailored for on-farm management, using the Internet to provide weather data to farmers, and evaluated its ease of use and acceptance by farmers and industry. Project cooperators worked directly with farmers and farm advisors to improve the prototype system, conducting on-farm tests, collecting soybean growth and yield data, and evaluating the soybean crop model integral to the DSS.
Work completed

We developed a simplified DSS, PCYield, for calculating in-season projections of yield using the CROPGRO-Soybean model. The PCYield software program interface was designed by project investigators working cooperatively with Weather Services International Corporation (WSI), and programmed by project investigators. A method was developed to link data from WSI to PCYield users. Initially, data were retrieved from the StratSoy computer in Illinois. During the second year, another link for downloading weather data was established at the University of Georgia.

Over a two-year period, we worked with farmers and industry consultants to field-test the software. WSI Corporation provided daily weather data for cooperating farmers' test fields across the US, and evaluated the product through their network of agriculture input providers.

The software was provided to all cooperators for evaluation.

Findings

We successfully enhanced the soybean model with a graphical user interface and an integrated link to commercial weather data. In most cases, farmers installed the software and downloaded weather data for their fields easily. A few difficulties occurred in some computers for reasons related to their specific configurations or to programming errors that were later corrected.

In cases where good soil and variety information were available, users found that yield projections were within 10% of field-measured yields. Agronomists working with WSI were very pleased with their customer responses to the product, and WSI asked for exclusive rights to PCYield.

We found the creation and delivery of software and training of users very time consuming, confirming our belief that industry must be involved for this technology to be made available to a large number of soybean farmers on a sustainable basis. We also confirmed the necessity of accurate variety, soil and weather information, in order to provide accurate yield potential projections and decision support to farmers.

Significance

PCYield was highly successful as a “proof of concept” product. It provided a way for soybean farmers to evaluate some decisions for their own weather and soil conditions, such as planting date, selecting a variety, timing irrigation, and replanting following crop damage. It is the first product of its kind to be incorporated by a major private company into a product for widespread distribution to soybean farmers.

PCYield’s acceptance by the private sector provides new and exciting opportunities for research integration and rapid technology transfer.
Evaluation of PCYield in Southern states

Mississippi State University, University of Georgia

Work completed

We completed extensive practical trials of the PCYield software, working with seventeen growers in seven states over the two year project period.

Each grower selected a field with one or two soil types and planted one to three varieties of soybeans.

Weather data for each field were downloaded from WSI Corporation servers, allowing the model to aid in irrigation decisions, predict harvest maturity and project expected yield.

Many fields had an automated weather station which could be remotely accessed by modems for comparison of weather data from WSI with data collected in the field.

We sampled the plants throughout the season to obtain growth rates and dry matter accumulation amounts for these specific varieties (see illustration below). At harvest time, yield was recorded for each variety on every field. Soil hydrological properties for the soils in the trials were sampled and measured.

Growers and researchers both used PCYield to analyze crop information, and consulted frequently about irrigation timing and harvest dates.

Findings

Growers found PCYield easy to use. In general, its integrated model predicted irrigation needs very well, and was satisfactory for expected yields.

Most growers used the program’s ability to predict relative yields to aid in decision support. Here the model performed well.

When the data from the automated weather stations were input into the model for 1997, final yield predictions were improved in some cases.

Model predictions of yield for 1997 were also improved by using a variety data file specific to the variety grown in the field, in lieu of generic variety files. The number of specific variety data files will increase as a result of our new project funded by the USB.

Significance

Overall, PCYield, and the WSI weather data available for it, are very useful tools for soybean farmers. They can increase growers’ confidence in irrigation scheduling and even help evaluate possible installation of irrigation for a specific field.

If available, locally collected rainfall data can significantly improve the accuracy of yield predictions. More options for use of rainfall data may be included in future versions of the software.
Evaluating PCYield for yield prediction in the Midwest  

**Work Completed**

We tested PCYield in three fields in Iowa in 1997 and in five fields in Kansas in both 1997 and 1998. Data on soil and variety, measurements of crop growth stage and plant weight, management information, and final yield and maturity information were collected. To rate its accuracy, PCYield was used to simulate growth and yield on each farm, using up-to-date weather data provided by WSI Corporation. Simulated results were compared with field-measured data.

In 1998, a training session was held for thirteen farmers, crop consultants, seed company representatives, and extension agents. The group evaluated PCYield, and provided suggested improvements to the software developers.

We adapted PCYield to predict county-level yields. The adapted system was tested for 1986-1996 for Cerro Gordo County, Iowa.

**Findings**

The error in yield prediction was less than five bu/ac in the 1997 Iowa on-farm tests. Similarly, in Kansas, the model performed well across both years, accounting for 86 percent of the observed yield variation (neglecting a partially flooded set of plots). The graph below shows the 1998 results.

In the training workshops, users found that rainfall and soil type are the most sensitive inputs for the DSS. The most difficult challenge for farmers is to select the proper modeled soil type for their field. Accuracy could likely be improved by allowing farmers to enter their own rainfall data measured near their field.

The adaptation to simulate county-level yields for Cerro-Gordo County, Iowa, explained 91% of the year-to-year variability (see graph above) for the 1986-1996 period. For most years, the model gave excellent yield predictions when used in early July or later.

**Significance**

Our results demonstrated the ability of PCYield to predict yields in farmers’ fields, but also illustrated the need to properly characterize individual varieties. The actual cultivars developed somewhat more slowly than idealized, maturity-group-average varieties used in by PCYield.

This is one of the first projects that has allowed widespread testing of the soybean model across many of the soybean production areas in the US. Model improvements made during the course of this project have already been helpful to other projects funded by soybean checkoff boards where the model is being used to analyze data or evaluate production strategies.

This work has provided researchers with the opportunity to work directly with growers on their farms. Many have learned valuable lessons from this direct interaction. Through this case study, researchers learned how growers initially view and subsequently adopt new technology, and observed the process of technology transfer from universities to farmers and agribusiness.
Improving the soybean model for use in widely varying weather and soil conditions

University of Florida, Iowa State University, and University of Georgia

Work Completed

We used data from three states to test the ability of the current soybean model to predict water uptake and yield for varying soils.

Modifications were made to the soil drainage, root growth and water uptake components of the model to determine if modifications could improve its performance in problem soils such as very heavy soils from Nebraska.

We also used data from Iowa to test the model’s representation of nitrogen balance and plant growth in cool seasons. Analysis showed that the original model was too sensitive to cool temperatures in the spring, causing it to significantly under-predict yield for some conditions.

Modifications were made to the relationship between temperature and nitrogen fixation in the model.

For both heavy soil and cool weather situations, we compared predicted and observed data for the original and newly revised models.

Findings

The original model predicted water uptake and yields for silt loam and sandy soils better than heavy soils.

The original model did not adequately account for heavy soils’ impeded root growth and water extraction (clumping). However, the revised model was able to simulate patterns of water extraction from the soil and showed more accurate predicted yield.

The revised model was shown to predict field results well in the cooler temperatures of Iowa.

Significance

Detailed evaluation of the ability of the soybean model to predict moisture use and yield across a number of soil and weather conditions has given us greater confidence in its use.

Improvements to the soybean model greatly improved its accuracy in heavy soils, in soils with known problems, and in cool weather conditions.

This work also showed the importance of having the correct soil characteristics for any field where PCYield is used to estimate yield. Future work should focus on practical and inexpensive methods for estimating soil parameters for specific fields or portions of fields.
Decision Support System Delivery and Enhancement

Create a process for the long-term, sustainable use of the DSS, including delivery, documentation, maintenance, and enhancement.

Crop model-based decision support systems cannot be widely used without the availability of necessary technical support, maintenance, and continual enhancement.

Researchers designed and produced mechanisms for easy access to information required by the DSS on a routine basis (weather, soil, and variety information) and worked with the private sector to perfect the approach chosen. Partnerships with consultants and engineers from the private sector enabled researchers to begin adapting tools developed by the project into commercial systems which could be made generally available to soybean producers.
Exclusive rights to PCYield awarded to private company

Weather Services International Corporation (WSI) requested exclusive distribution rights for PCYield from the United Soybean Board (USB). Attorneys at USB, the University of Florida, and Kansas State University approved the transfer of PCYield distribution rights to WSI.

Findings

WSI now has exclusive rights to the private distribution of PCYield.

The agreement stipulates that the University of Florida will retain the PCYield trademark. The soybean model itself remains in the public domain. USB investigators shall retain access to PCYield for research purposes, and WSI will continue to cooperate with USB investigators by providing access to real time weather data at selected sites across the US. WSI will also permit use of their Emerge® agricultural weather data product for research purposes.

WSI has now included PCYield in Emerge, which is being marketed across the US. The company has invested their own resources to create PCYield corn and wheat products. WSI also plans to develop software for additional crops.

Significance

This is a landmark agreement. It confirms the utility of the DSS concept for technology transfer, and provides a model for future cooperation between research and industry in the packaging and delivery of research on soybean production.

Comparison of field-collected and commercial weather data

Work Completed

Accurate daily weather information is critical for practical on-farm use of DSS tools. The installation and maintenance cost of weather collection instruments is high, making commercially provided farm-specific weather a viable alternative.

We worked with WSI Corporation to evaluate the reliability and accuracy of such a data source in 42 locations across the US. Daily weather data were obtained from the sites using automatic weather stations installed at farmers’ fields or on experiment stations (see graph at below left). Daily data were also provided by WSI for these sites, based on collected latitude and longitude information.

We compared the accuracy of the commercial data, which is interpolated from nearby reporting stations and computed with remote sensing, by comparison to data collected at the sites.

Both commercial and field-collected weather data were used to simulate soybean production at each site. Results were similar for both data sources.

Findings

Daily maximum temperatures provided by WSI were highly accurate (correlations ranged from 0.97-0.99). Daily minimum temperatures were slightly less accurate (0.93-0.96). Solar radiation data were highly accurate for most locations (0.95-0.97). Daily rainfall amounts were the least accurate (0.63 to 0.79). However, cumulative rainfall amounts were similar in most cases.
Comparison of field-collected and commercial weather data

University of Georgia

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Significance

Soybean farmers found the daily weather data available via the Internet an accurate and valuable source of information. Our results show that in most cases commercial weather data can be used with DSS tools such as PCYield with little loss of accuracy compared to locally collected weather data. PCYield may be modified to allow growers to record rainfall observed using their own rain gauges, providing more flexibility to those who do record their own rainfall amounts.

Application of soybean variety trial data for estimating parameters of new varieties

University of Florida, University of Georgia

Work completed

Most agricultural experiment stations and seed companies collect detailed variety trial data for both public and private varieties. These stations are diverse, representing the different soil and climatic conditions of the soybean growing region.

We developed procedures for using variety trial information to estimate variety-specific parameters for the soybean crop model, using trial data collected from six Georgia locations over seven years.

Findings

The variety trials in this study provided adequate information to estimate most parameters for the soybean crop model. Because the variety trial data do not include detailed growth analysis measurements, we had to use results from previous research studies to develop relationships among parameters. However, these previously defined relationships, along with the limited observations collected for each variety in these trials, showed considerable promise for further development and application.

Significance

Maintenance of up-to-date variety trial information will allow farmers to use computer-based technologies such as the DSS with the latest varieties released by both public and private soybean breeders.

In this project, we learned that variety trial data could be used to estimate parameters needed for new cultivars. This work was very important in defining objectives for the new USB project “Integrating Genetics and Precision Farming Information into Decision Support Systems.”
Statistical methods for predicting specific cultivar yields

Work Completed

Practical, easy to implement methods are needed to predict yield for specific, modern cultivars. We developed a practical approach for providing an alternative to the more complicated procedures being evaluated by other project researchers. We combined statistical analysis of soybean variety trial data with the soybean crop model.

We identified methods for classification of soybean cultivars by their yield potential in good or poor growing conditions. We used yield data from over 8,400 cultivar-location-year combinations from 1981-1997 North Carolina Official Variety Trials (OVT). Equations were generated to predict cultivar yield in different environments from average maturity group yield.

Findings

Fitting equations to OVT yield data from multiple years and/or locations appears to be a promising way to incorporate cultivar differences into the DSS. Fifty-seven percent of yield variation between cultivars in Plymouth 1997 OVT trials was accounted for by equations fit to yield data from previous OVT trials at multiple locations.

Significance

This research identified a simple technique for adjusting PCYield and SoyDSS yield predictions to account for cultivar differences in response to environmental conditions.

Our method uses information already being collected in variety trials (frequently for one or two years prior to cultivar release). This approach should be evaluated for other states and years and compared to the correctly used methods. If successful, this approach could allow research to keep up with the rapid turnover in cultivars.

![Comparison of predicted and observed soybean yield in North Carolina](image)
Using AgSoilPro to create customized soil files from limited soil information

Ohio State University

Work Completed
A major problem with agricultural decision aids is the difficulty in obtaining realistic input parameters, particularly for soil inputs. Soil properties may vary both temporally and spatially.

We developed the AgSoilPro utility program for use with crop simulation models where site-specific soil inputs are required and there is limited information to generate them. AgSoilPro can generate soil files for SoyDSS and PCYield models.

Findings

When there are no data available, the program utilizes user supplied details to select representative soil data from the program’s repository of baseline soil files. Additional soil data can be collected and encoded in database files queried by the program. Once these soil data are retrieved by the program, they may be further amended on the basis of “expert knowledge.” Users can enter their own specific data by choosing either the edit option or manual inputs.

The program provides graphical displays of information about soil parameters users are about to enter, so the possible effects of a selected input are better understood.

Significance

AgSoilPro allows soybean DSS users who have little data about their soil to build an accurate set of soil files with an easy-to-use graphical interface. This functionality makes SoyDSS and PCYield a viable option for a wider range of users.

Developing customized weed and herbicide databases for SoyDSS

North Carolina State University

Work Completed
In this project, a previously developed weed and herbicide selection program (HADSS) was modified for incorporation into SoyDSS for use in all soybean producing states.

We created a program that makes it easier for weed scientists to modify and update information used by SoyDSS to predict crop yield losses due to weeds for use in their own states.

Methods for ranking different herbicide treatments based on efficacy against the weeds present in the field were also developed.

Findings

Using this program, weed scientists in North Carolina, Georgia, and Mississippi developed state-specific databases. These were provided to DSS programmers and subsequently included in SoyDSS.

Significance

The addition of the weed and herbicide selection program has greatly improved farmers’ ability to make weed management decisions based on analysis of conditions specific to each site.

Results from tests in three states enabled award of a new federal grant which should allow rapid development of weed and herbicide databases for eleven Southern states.
Enhancing the DSS software program

Kansas State University, University of Florida, North Carolina State University

Work Completed

A major effort was made to integrate our various research efforts into our overall decision support system (SoyDSS).

Applications of PCYield are limited to planting date, variety, and irrigation projections for specific fields. However, SoyDSS incorporates those capabilities and adds additional features for analysis of many soybean management alternatives for specific fields. SoyDSS incorporates the soybean model, as well as herbicide, soil, and other decision modules into one system.

A computer user interface for SoyDSS was programmed to allow users to input information about their fields, weeds, prices, and management practices. The interface also allows users to easily compare various decisions by simulating yield and profits for each decision.

The pre-season decision modules (shown in figure below) include average yield prediction, variety and planting date selection, herbicide recommendation, irrigation, and pricing analysis.

The results of all analyses can be tabulated from several perspectives including basic yield, crop timing, economics, water use, fertility aspects, weather summary, and environmental issues.

In-season modules include yield forecasting, irrigation needs, and replant decision support. Multiple management scenarios can be compared within both sets of modules.

The SoyDSS program was provided to all investigators and cooperators on CD-ROM.

Findings & Significance

The completion of SoyDSS provides an integrated product which can be used by researchers, extension agents, crop consultants, and others without restrictions. This was important because exclusive rights to PCYield were granted to WSI Corporation for distribution through their cooperating agricultural distributor (UAP).

Preliminary evaluations of the complete SoyDSS indicate that it may be most practical for use by consultants, extension, and service providers, not by farmers directly, since it requires much more time to operate than PCYield.

However, the completion of the DSS was a very important product of our research program. Users of PCYield are already asking for additional capabilities, many of which have already been incorporated into SoyDSS. Thus, the product provides “proof of concept” for continued evolution of the soybean DSS products.
Integrating New Research in the Decision Support System

Investigate methods for integrating new research results into DSS components, enhancing capabilities and value for soybean producers

New knowledge of soybean production systems and site-specific management techniques are being developed in many research institutions in the U.S. The ultimate success of the decision support system approach depends on the integration of this new scientific information and its application to contemporary problems.

Researchers must integrate new findings into the soybean crop model and DSS in ways that the private sector can incorporate into their commercial DSS products. This will allow the benefits of research to reach producers rapidly and sustainably.

This objective was focused on two areas: (1) characterizing drought tolerant varieties and understanding how they achieve tolerance, and (2) investigating use of the crop model to understand reasons for spatial variability of yield in precision farming fields.
Work Completed

Soybean management practices that capitalize on water stress, such as variety selection and possibly population, will likely provide the largest pay-off in precision farming. Proper selection of varieties across a field will likely be the most important variable rate soybean management decision.

We developed techniques to calibrate CROPGRO-Soybean, the soybean crop model used in PCYield and SoyDSS, to explain the role of water stress in creating spatial yield variability.

We also developed methods to use the soybean crop model to evaluate the profit increase for switching to a Soybean Cyst Nematode (SCN) resistant variety in a field where SCN populations were measured.

We demonstrated the applicability of these methods for corn by using the the corn crop model in a field near Ames, Iowa.

Findings

We found that, in one field, 67% of soybean yield variability could be explained by water stress.

SCN effects were incorporated into the model from work resulting from the Soybean Research & Development Council (SRDC) funded “Yields Project,” and applied to a farm near Perry, Iowa. Results showed a 5 to 7 bu/ac increase in field level yields for the SCN resistant varieties.

This model-based analysis was also extended to evaluate spatial variability of corn yields. Results showed that 59% of corn yield variability could be attributed to water stress and population differences. This work confirms the potential of using the crop model analysis approach for soybean-corn rotations.

Significance

We have demonstrated that crop models are valuable tools for analyzing causes of yield variability, and evaluating economic performance of some prescriptions. Specifically, crop models give us a way to analyze multiple layers of data, and determine how various factors interact during the season to limit yields across a field.

Work on this project has been used to leverage further impact from other corn and soybean checkoff funded projects in Iowa, by analyzing data collected by numerous university and USDA scientists.

Preliminary results from this project have been noted by industry, and several companies have adopted these techniques internally to analyze their own data sets. The results of this project helped encourage industry interest in participating in our subsequent USB project, “Integrating Genetics and Precision Farming Information into Decision Support Systems.”
Using remote sensing data to define crop management units for precision farming

**University of Florida, Michigan State University**

**Work Completed**

Site-specific crop and soil management requires the division of fields into units. Remote sensing data were tested for their ability to accomplish this task. Corn and soybean fields in Michigan were imaged with infrared remote sensing several times during the season in 1998. Based on the infrared data, we calculated indexes that enabled division of fields into units with different yield potential.

**Findings**

Infrared images showed clear patterns which seemed to relate quite strongly with spectral indexes obtained from remote sensing data (see examples at right).

**Significance**

Infrared imaging could be extremely useful for site-specific management because it provides very timely information at an affordable cost. Further research using techniques developed in this project will focus on year-to-year variability and applicability in management recommendations.

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Evaluating the potential for increasing yield through variable planting of cultivars in single fields

**North Carolina State University**

**Work Completed**

Precision farming concepts may provide soybean farmers with methods to increase yield and/or reduce costs of production. It may be possible to increase yields by varying cultivars across a field.

We evaluated the potential for increasing yield through variable planting of soybean varieties across a field, and identified methods for determining where to plant each cultivar.

Two cultivars were planted in alternating strips across test fields. One cultivar (Holladay) was identified (based on OVT data collected in previous years) as adapted to high-yielding conditions, and the other (DP3589) as adapted to low-yielding conditions. Fields were harvested using a yield monitor.

**Findings**

There was a 6 to 7 bushel per acre yield advantage to variable planting of soybean varieties in different areas of a field based on their adaptation to that particular field environment. Soil water-holding capacity was the most important factor.

**Significance**

Studies proved the value of breeding soybean varieties for maximum performance in specific environments rather than breeding for average performance across a range of environments.
Comparing growth of genotypes differing in drought tolerance

Work Completed
We compared growth of four genotypes differing in drought tolerance under varying water stress conditions. Rain exclusion shelters were used to establish three different stress regimes: well-watered, stress during flowering, and stress during pod fill. Information on crop growth and soil water status were collected throughout the growing season. Actual growth was compared to that predicted using the current version of the DSS to identify changes needed to improve DSS predictions.

Findings
Holladay and Graham varieties wilted earlier under drought stress than PI416937 and Buckshot. They also senesced leaves earlier. On a relative basis, yield of Holladay and Graham was reduced more under stress conditions than yield of Buckshot or PI. Yield of Graham was reduced more than 40% by both early and late stress, whereas yield of Buckshot was reduced by 21% in the early stress and by 33% in the late stress.

Significance
This research clearly demonstrated genetic differences in soybean drought tolerance. By identifying and characterizing these differences, farmers may be able to select varieties more suited to their known field conditions. This knowledge may also help plant breeders further exploit this characteristic in future breeding efforts.

Evaluating drought response of modern soybean varieties to improve the soybean model

Work Completed
We evaluated the drought response of three modern indeterminate soybean varieties (Asgrow 3244, Macon, Pioneer 9395) subject to drought stresses during the flowering and pod fill stages of soybean growth.

A rain exclusion shelter established the drought conditions during the specified growth stages.

Growth stage, leaf area index, soybean development, root growth, and soil moisture were measured weekly from emergence through maturity. Data collected were used to modify the soybean genetic coefficients to represent modern varieties grown in the Midwest, and to incorporate drought response characteristics in the soybean model used in the DSS. The experiment was conducted for two years (1997 and 1998).

Findings
The three modern varieties yielded significantly more than the older Williams 82 variety. Timing of drought stress was important; all varieties were more sensitive to drought during the pod-fill growth phase across both years.

Root length densities varied by variety, but results were not consistent across years. However, deep water extraction was greater for the modern varieties, indicating that they may have reduced stress by gaining access to the deeper water.

Significance
There are differences in drought tolerance between the older soybean variety and the newer soybean varieties used in this study.

The detailed measurements made in this study were highly useful in demonstrating that the CROPGRO-soybean crop model could simulate differences among varieties due to their differences in physiological responses to drought. Future versions of this model can incorporate information on drought tolerance.
Modeling drought tolerance of soybean cultivars

University of Florida, Illinois State Water Survey, North Carolina State University

Work Completed

To understand and model the mechanisms of drought tolerance, we subjected selected cultivars to water deficits during flowering and pod-filling growth phases in North Carolina and Illinois. The soybean model was used to analyze data from both locations to help interpret results relative to observed and modeled varietal differences in drought tolerance.

Observed cultivar traits were modeled by adjusting model variables for the high yielding drought tolerant cultivars.

Findings

Cultivar differences were observed in yield potential under no-stress as well as under drought stress conditions. Drought decreased the seed yield of cultivars by about 20%. Water deficits during flowering phase decreased the leaf area index of cultivars significantly compared to the water deficits during pod-filling phase.

High yielding drought tolerant cultivars had greater water extraction from the sub-soil compared to the low yielding drought susceptible cultivars. This could be attributed to their deeper rooting system compared to that of susceptible cultivars. Deeper rooting resulted in more water use by the drought tolerant cultivars during the season. This cultivar trait was modeled by a greater root extension rate and deeper root profile function for the drought tolerant cultivars.

Drought tolerant cultivars also had greater water use efficiency (biomass/transpiration) than the susceptible cultivars. A greater proportion of evapo-transpiration was lost as transpiration rather than soil evaporation, producing more biomass per unit of water used. These cultivar traits were modeled by setting higher values of leaf photosynthesis rate (LFMAX) for the high yielding drought tolerant cultivars.

Drought tolerant cultivars had greater partitioning efficiency and partitioned more assimilates to the pods and seeds than the susceptible cultivars. This was modeled by adjusting the partitioning coefficients of the cultivars.

Significance

Adjustments in species and cultivar-specific coefficients (genetic coefficients) resulted in accurate simulation of soil water extraction and yield of cultivars both under drought and well watered situations at both locations.

CROPGRO-Soybean, the crop model used in PCYield and SoyDSS, can be used to simulate the drought response of soybean cultivars in various drought stress environments. However, further model testing is needed under extreme drought situations.

More soil water was extracted by drought tolerant varieties
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