EVALUATION OF OPTICAL SENSORS FOR THEIR USE IN DETERMINING VARIABLE-RATE HARVEST AID APPLICATIONS

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Abstract

Cotton defoliation aids in a timely and efficient harvest by removing leaves and promoting boll opening. Environmental variation (soil conditions, slope, insects, weeds, etc.) in cotton production fields often leads to varied crop maturity within a single field. Real time variable rate technology can account for the variation emerging from year to year in a field

Data were collected from multiple studies at the Oklahoma State University's Southwest Research and Extension Center in Altus, OK (SWREC) to determine a prescription application rate for cotton harvest aids using the GreenSeeker® optical sensor system. A self-propelled sprayer system was modified to accommodate a seven row sensor system used for measuring plant Normalized Difference Vegetation Index (NDVI). Data were collected from 2007-2010 from multiple studies at the SWREC. Multiple studies were used to ensure similar variability was found in the research plots as is seen in producers' fields across the southwest region of Oklahoma. Along with the NDVI data Node above cracked boll (NACB), percent open boll (% Open) data, and heat units for the growing season were collected from each of the studies.

Promising results were observed from the first year of study even though the experiment was terminated due to an early frost. A full experiment was not possible during the 2010 growing season due to an accidental defoliation caused by spray drift from a neighboring field. Thus relationships were compared with NDVI and NACB and % Open. A good correlation was found between the percent of defoliation and NDVI numbers in the preliminary study in 2008 before it was terminated. The correlation can be used with future data to accurately predict a prescription rate of harvest aid needed based on specific crop maturity levels. The prescription equation will help to account for most of the field and crop maturity variability.

Introduction

Cotton is a perennial plant and unique in nature. For cotton, vegetative and reproductive growth occurs simultaneously. The relationship of vegetative and reproductive growth causes differences in maturity where there are non-uniform growing conditions. Environmental variation (soil conditions, slope, insects, weeds, etc.) in cotton production fields often leads to varied crop maturity within a region, farm in in most cases within a single field. Real time variable rate technology can help to account for the variation emerging from year to year within a field. Although not exact, timing of harvest aid applications are generally guided by such techniques as % Open, NACB, and the cut boll technique (Banks, 2001). Due to the every changing maturity of the cotton plant based on environmental conditions harvest aids need to be applied based on a current plant condition to be effective, thus a uniform rate applied over an entire field based on field average plant maturity may leave the producer with undesired results. The uniform rate may work well in areas at or beyond the average crop maturity level but due to environmental variation will not be effective in areas of the field where the crop is behind in growth.

Plants of different maturity levels will have different numbers of NACB and % Open. The varied maturity levels will also lead to difference in leaf color. From the remote sensing perspective, plants treated with either a defoliant or desiccant should have different spectral responses over time (Yang, et al. 2003). Though many vegetative indices exist, the most common and highly correlated index is NDVI (Tucker et al., 1980; Plant et al., 2000). In addition strong correlations have also been observed between NDVI and height of the top five nodes in cotton plants

(Kirkpatrick et al., 2005). The spectral differences in the crop produced by varied levels of crop maturity and chemical applications will facilitate a separation of the NDVI values collected from the plants. The differences can then be correlated to plant maturity and chemical effectiveness to develop a prescription application rate based on plant NDVI. This prescription can be used real-time with a variable rate applicator to apply cotton harvest aids accounting for crop environmental differences. Taylor et al. 2010 reported an average reduction in use of 8% of harvest aid material over three site years using variable rate applications. The main objective of this study was to develop relationships between crop maturity parameters and NDVI to aid in developing a robust prescription equation for applying variable rate harvest aid chemicals to cotton at the end of the growing season.

Materials and Methods

This experiment includes data collected over a four year time span from various cotton experiments to aid in determining cotton maturity and its correlation with NDVI using the GreenSeeker® optical sensor. The data were collected from Altus, OK from 2008 to 2010. The cotton studies used for data collection were a nitrogen study with variable rate plots consisting of 0, 40, 60, 80, and 120 pounds per acre, a plant growth regulator (PGR) study, a long term nutrient study, and typical grower practices. Various studies were used to ensure variability was included with the data to compensate for the variability seen in producers' fields. The data collected included NDVI, the number of nodes above cracked boll, the percentage of open bolls on a plant, and heat units for the growing season.

In 2008 and 2010 prescription rates were applied to the test fields to aid in developing an NDVI based prescription rate. In 2008 the experiment was terminated due to an early frost and during 2010 the experiment was terminated due to a spray drift defoliation that occurred around the time of the first chemical application to the crop. An initial prescription equation is not possible out of the current data due to the terminated experiments, thus crop maturity relationships have been looked at.

Initial data were collected from plants in various locations within the experimental plots to help account for spatial variability of the field. NDVI was collected first, and then plant data was collected by hand the same day the sensor readings were collected. In most cases NDVI was collected using a seven sensor system. The seven sensor system used four sensors to collect data over the four rows and the other three sensors to collect data from in-between the rows. The data were separated using GIS software to differentiate between the over row and between row data. The method used in 2010 for collecting plant data was like the earlier methods and consisted of using ten plants at each collection site. On each of the ten plants the total number of bolls was counted and recorded along with the number of open bolls to obtain the percent open. The number of nodes above the highest cracked boll was also counted and recorded from each of the ten plants.

The data were normalized using the heat units downloaded from the Oklahoma Mesonet weather site. A general start of dry down date of September 1 was selected to have a beginning point to compare the seasons of data. Some studies had multiple dates of collection while others only had single collection dates (Table 1).

Table 1. Studies used in the experiments and data collection dates.

Study Used	**Data Collection Date/s**
Nitrogen	9-10-09, 9-24-09, 9-30-09
Long Term Nutrient	9-23-08
Plant Growth Regulator	9-22-08
GreenSeeker	9-23-08
Defoliation	9-29-10

Growing seasons are never uniform from year to year. In this case all of the cotton used in the studies was planted around the 15th of May. Even though the planting dates are similar the environmental conditions changed greatly from year to year. The increase or decrease in temperature at specific times during the dry down period can cause the crops to mature more quickly or slowly. The incorporation of heat units with the data to aid in the normalization process helps in accounting for the environmental variations from year to year and location to location. The differences in Heat Units can be viewed in Table 2.

Table 2. Heat units collected from 9-1 each year.

Collection Date	Heat Units from 9-1
9-22-08	258.3
9-23-08	274.2
9-10-09	144.6
9-24-09	270.3
9-30-09	303.2
9-29-10	438.7

As can be seen from Table 2 the 2008 and 2009 growing seasons were very similar with the regard to heat units during the dry down period. The 2010 season was much hotter and accumulated more heat units, thus on the same approximate date of collection the cotton was more mature than that of previous years.

Results and Discussion

A relationship was analyzed between NACB and % Open to ensure there was a strong enough correlation between the two plant parameters to use in predicting the crop maturity levels. A negative correlation was found between the two plant parameters, as the NACB decreases the % Open increases (Figure 1). This relationship is expected because a more mature plant will have a lower number of NACB and a higher percentage of open bolls.

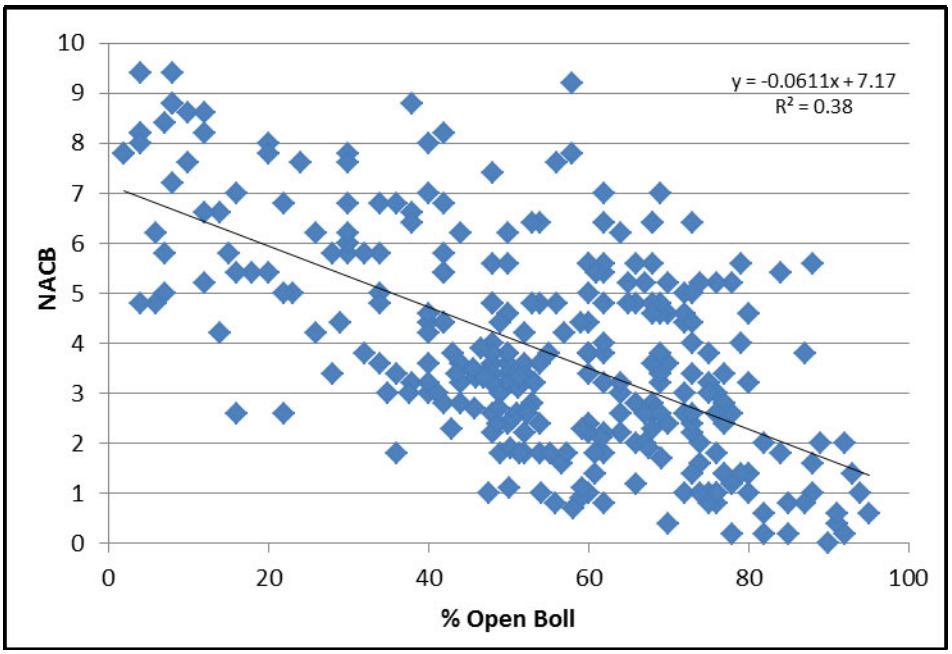

Figure 1. Inverse relationship of NACB and % Open collected from seven studies.

Since a relationship was found between the two plant parameters the data was then compared to NDVI taken at the same time as the plant parameters. The raw NACB data did not present as strong of a relationship (R^2=0.20) when correlated with NDVI. The data being collected from so many various maturity levels did not allow for a very good trend. The plants had too much spatial and environmental variability for the data to have much meaning between the three years sampled. The data did have a positive relationship meaning that as the NACB increased the NDVI also increased. This means that less mature plants give a higher NDVI value (Figure 2) because the plants leaves are greener than more mature plants during dry down. The same general trend was seen once the data was normalized using the heat units for the specific collection date. A better correlation was found (Figure 3) with the normalized data. The difference made by normalizing the data by using heat units was that the individual studies could be

differentiated from each other more easily than before (Figure 4). Plants that were stressed from specific factors such as a lack of nitrogen had a higher maturity level than those that were under ideal growing conditions. Faster maturing stressed plants can be seen throughout the data collected in both NACB and % Open.

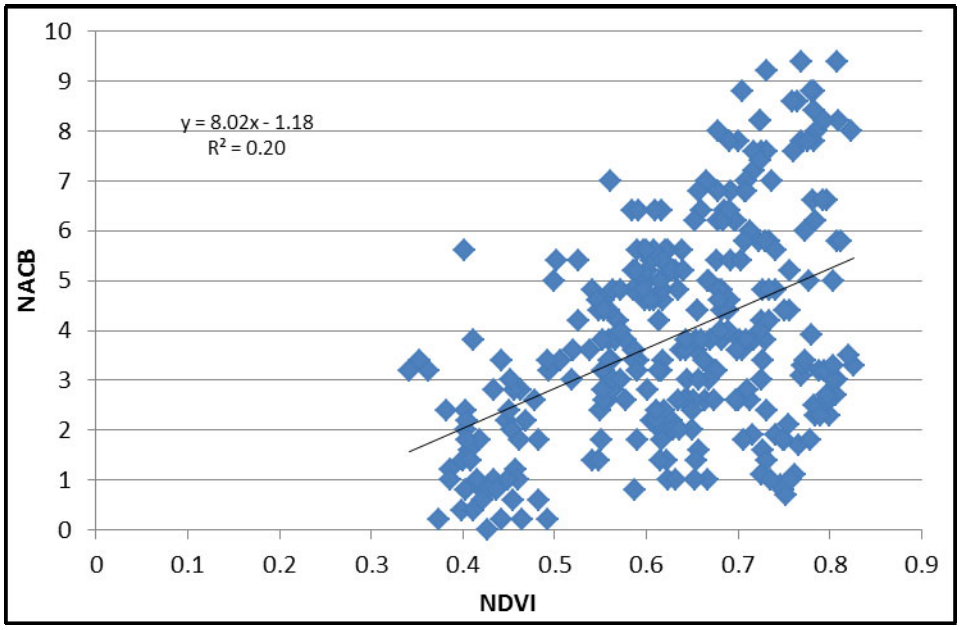

Figure 2. NACB vs. NDVI collected from seven data sets.

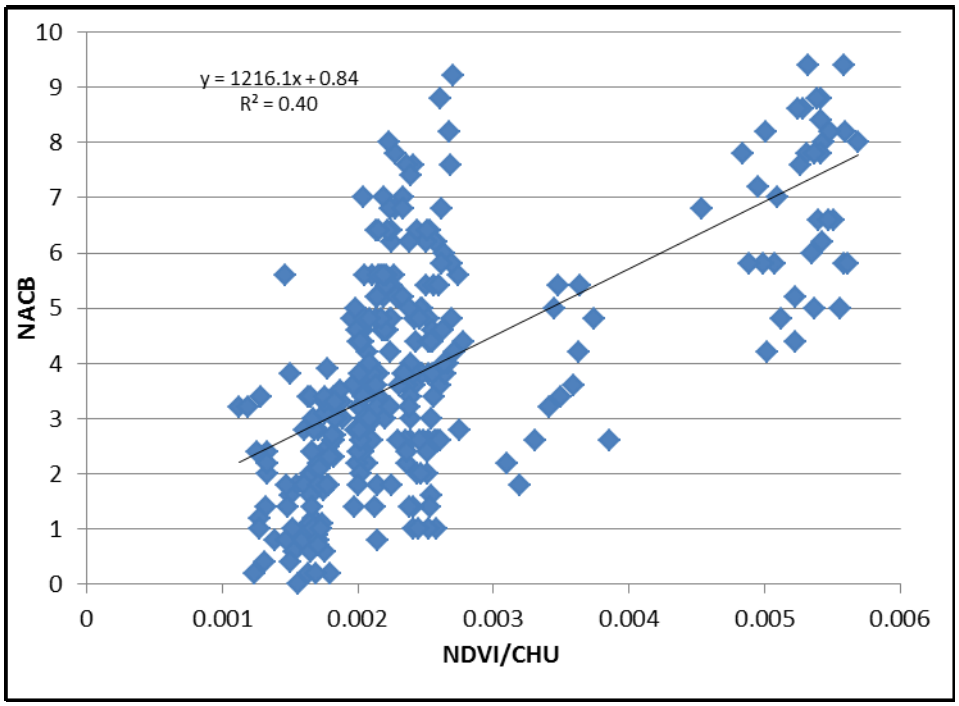

Figure 3. NACB data vs. NDVI normalized using heat units.

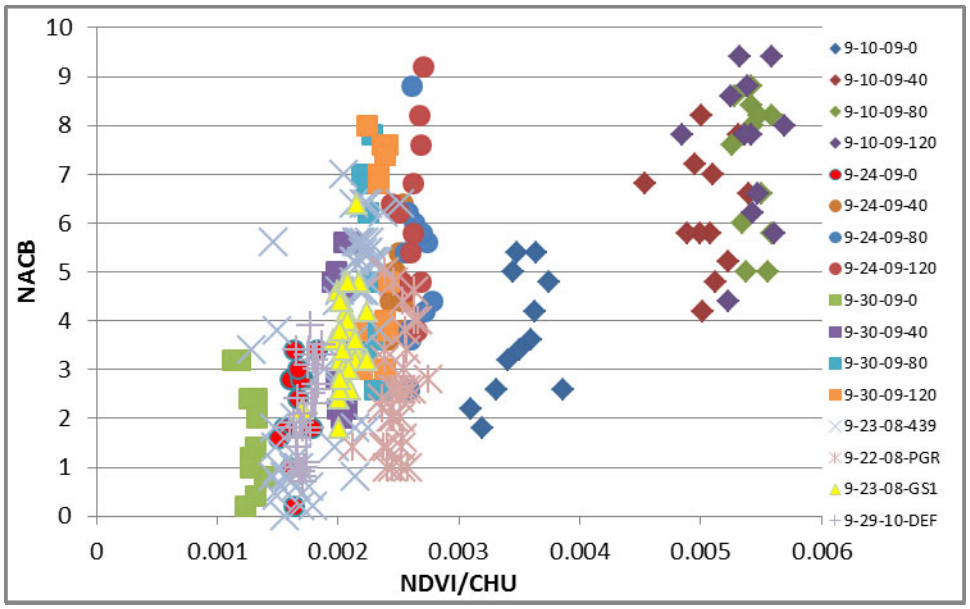

Figure 4. NACB data normalized and grouped by individual study.

As is viewed from the above figures normalizing the data using the heat units from September 1 formed a stronger relationship between NACB and NDVI. More ways of normalizing the data need to be explored to ensure the most accurate data possible is being used for the application of harvest aid materials.

Similar to the NACB data the % Open data did not have a very strong correlation when it was not normalized. However the % Open seems to have a stronger correlation with NDVI than did the NACB data. This could be because of growth and variety differences amongst the studies. Certain varieties may have higher vegetative growth at the end of the season than others. Figure 5 shows the raw percent open boll data. It represents a negative relationship with NDVI. As the plant has a higher number of open bolls the NDVI will be lower. The negative relationship occurs because a plant with more open bolls will be more mature and have less green in its leaves.

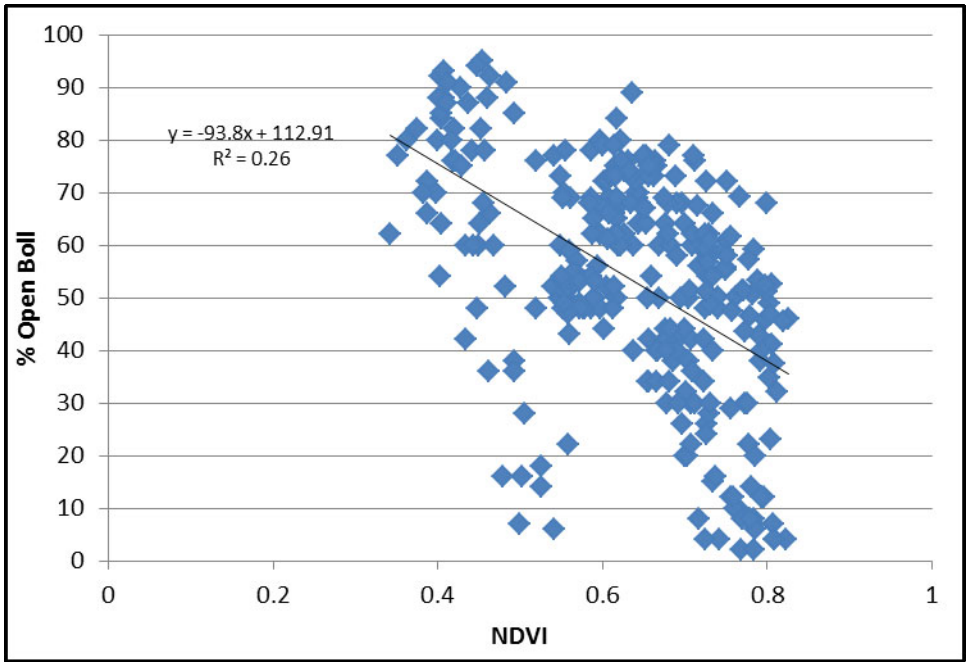

Figure 5. % Open Boll data vs. NDVI collected from seven data sets.

After the % Open data was normalized (Figure 6) using heat units an almost identical inverse trend to that of the NACB data was formed. This is expected since as the plant matures the NACB number goes down and the number of open bolls increases. The individual studies are more evident, as they were with the NACB data, once the data was normalized (Figure 7).

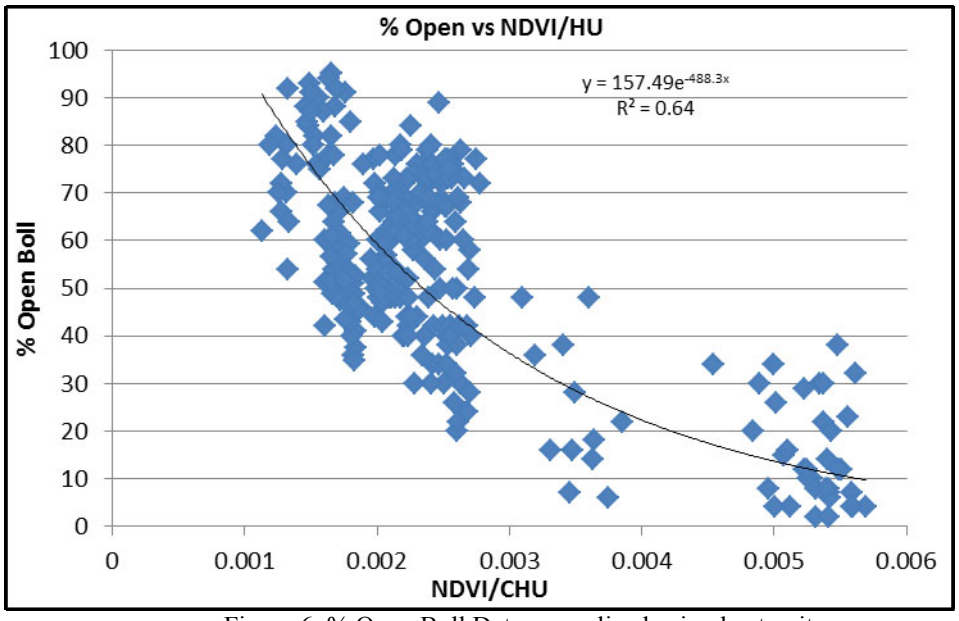

Figure 6. % Open Boll Data normalized using heat units.

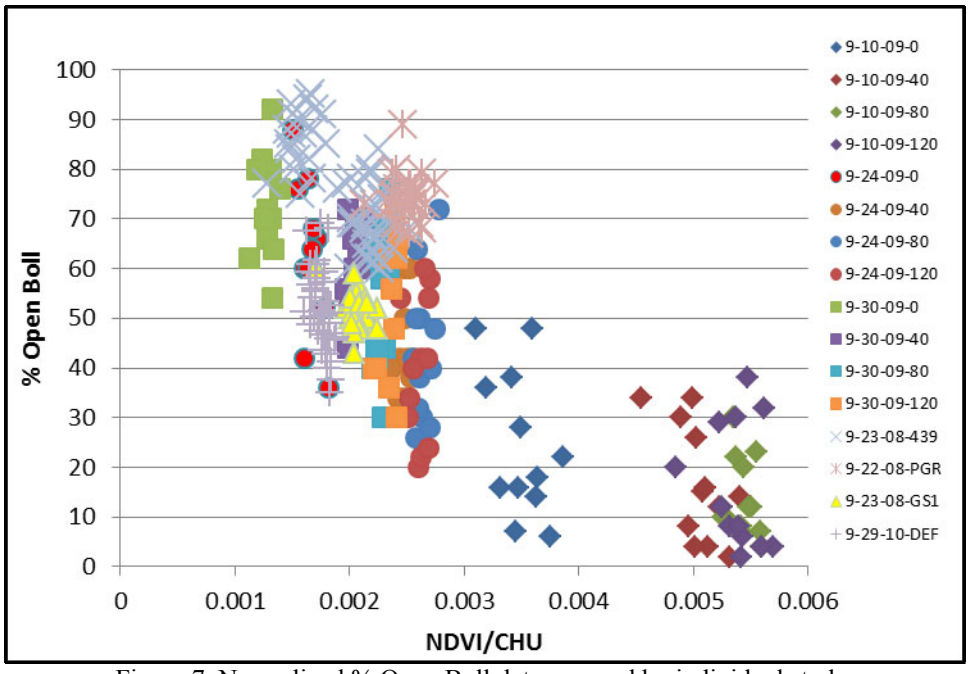

Figure 7. Normalized % Open Boll data grouped by individual study.

Both NACB and % Open have relationships with NDVI especially when normalized using heat units from the beginning of dry down. NACB has a weaker relationship than does % Open but that does not necessarily mean that it should not be included in a prescription equation for harvest aid chemical application.

A future study needs to complete the beginning of this study and have actual chemical rates applied to the field in variable rate, in the same way as was started in 2008 and 2010 before the experiments were terminated. The

application of chemicals along with the plant maturity data such as NACB and % Open combined with NDVI will allow for the development of a prescription equation. Heat units should still be included in the data to help account for environmental differences from year to year and field to field, unless a better way to normalize the data is found. In either case some way to normalize the data to account for differences in weather patterns should be included in this prescription equation.

The current relationships of the data are not strong enough to make a strong prescription equation that could currently be used for real-time variable rate application of harvest aid chemicals. So much end of season variability is present in cotton fields that a current recommendation needs to be used to accurately apply the correct amounts of chemicals for proper defoliation, boll opening and desiccation.

Summary

Relationships have been found between specific crop maturity data and NDVI readings from the GreenSeeker® optical sensor. These relationships are stronger if some sort of normalization can be applied to the data to account for spatial and environmental differences in cotton production. In this research study heat units from the start of dry down were used to normalize the data and made a visible difference in the R^2 values of the trend lines.

The percent open boll data currently seems to have the strongest relationship with NDVI, but this does not mean that NACB or other factors should be excluded from the development of a prescription harvest aid equation. A combination of the two plant parameters might prove more useful than one alone.

A study where actual application efficiency data can be evaluated needs to be completed. This study will help to determine the relationship between the chemical rates and the plant maturity parameter data. At this point the data is not strong enough to support a robust generic prescription equation.

Acknowledgements

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