SCSB Final Report

General Information

Principal Investigator(s) Name(s): C. Nathan Hancock (USCA) and Kendall Kirk (Clemson)
Organization: University of South Carolina Aiken
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Quarter: Final report

Proposal Information

Title: High-throughput image analysis for soybean nutrient deficiency and in-season yield estimate prediction
Amount Expended to Date: $5000

Project Summary

Our goal is to develop tools that allow soybean farmers to use digital image analysis to diagnose nutrition and disease problems. This requires that we build models for how visual factors (color, hue, and brightness…) relate to plant health and yield. This year, we started the process of calibrating our image analysis capacities by focusing on nitrogen deficiency. In order to create nitrogen deficiency, we used two soybean mutants with known inability to perform nitrogen fixation. Analyzing these plants manually (height, nutrition, and yield) and with image analysis allowed us to determine which image components correlated with soybean field performance.

A replicated field trial was performed in an irrigated research plot at the Clemson University Edisto REC. Aerial images were captured periodically (V2, V4, and R1), using a drone and manual measurements of height, leaf nutrition, and yield were taken at the appropriate stages. The images were analyzed by correlating the treatments (mutants vs. wild type) with specific areas of the image and classifying each pixel as a plant or non-plant. The original image and classified digital output of the image can be seen in Figure 1. Colorspace histograms were then generated for plant pixels in each plot, classifying each plant pixel into one of 26 divisions for each of the red, green, and blue colorspaces. By plot, fractions of plant pixels in each of the 26 colorspace divisions for each of the three colors were then calculated. Examples of the histograms can be seen in Figure 2 for two of the plots in the study.

Using his data, stepwise linear regression models were developed using pixel color data extracted from the aerial imagery at the time of leaf tissue sampling to seek to predict leaf N and yield estimates. Figure 3 shows predicted vs. actual leaf nitrogen content for one of the developed models (R^2 = 0.94) along with parameter estimates for the model. Figure 4 shows predicted vs. actual yield for one of the developed models (R^2 = 0.94). The results from this initial data set are promising. We have shown that the nodulation deficient mutants produced visible differences that can be detected by image analysis. We also have been able to show that these visible differences correlate directly with yield. The models developed here are promising because they suggest that aerial imagery data can be used for prediction of leaf nitrogen and in-season estimation of yield. At this time we do not have enough data to determine if these models would be suitable for providing farmers with mechanisms to rescue nitrogen deficient plants, but we hope to test this in the next round of experiments. Additional research should allow us to test additional variables (i.e. other nutrients) and to generate and vet of robust models that will help farmers make in season decisions.

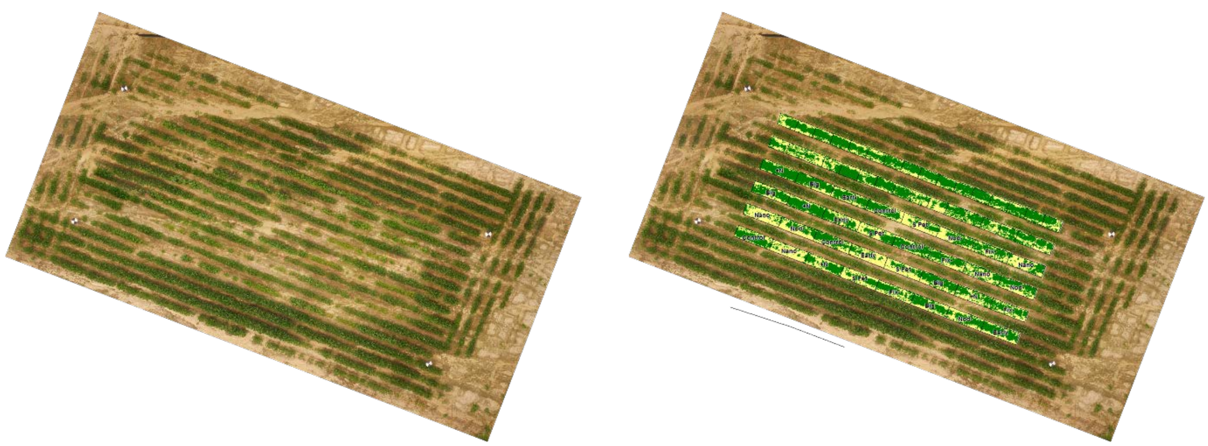
Key Performance Indicators

Our goals were to make direct comparison of aerial color analysis to tissue analysis and yield data. This was completed as proposed, allowing us to perform statistically sound analysis. In addition to this, we were able to look at the effects of nitrogen fertility on seed quality, seed weight, and plant height.

Next Steps

The researchers are preparing a follow up proposal that builds on this experience. We now have additional nodulation deficient mutant seeds, so will be able to perform a detailed analysis of what level of nitrogen fertilization would be needed to rescue nodulation deficient plants.

Additional Information



(a) (b)

Figure 1. Raw image of the plots on 25 Jul 2018 (a) and digitally classified pixel output of the image by plot (b).

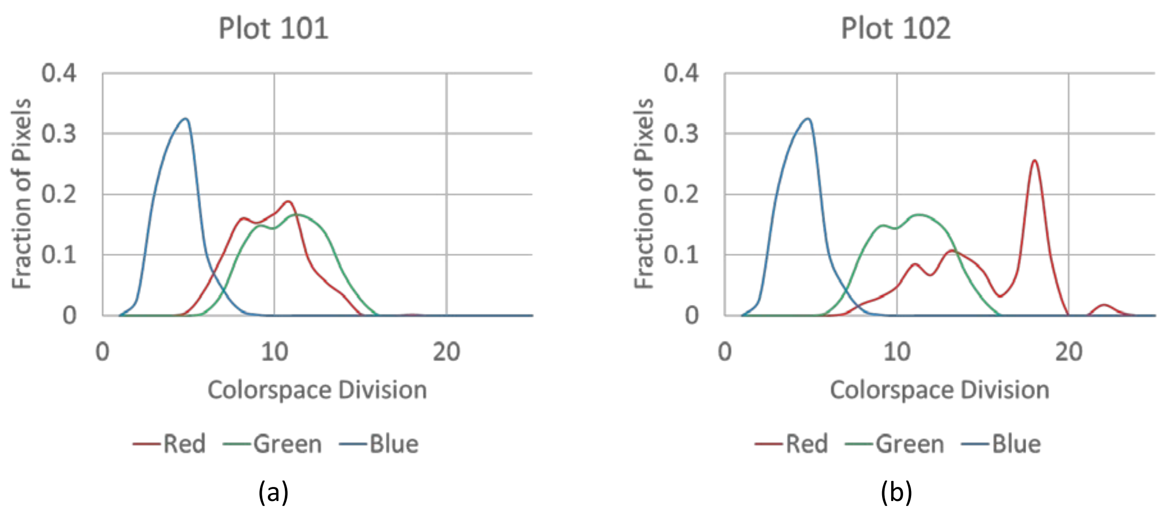
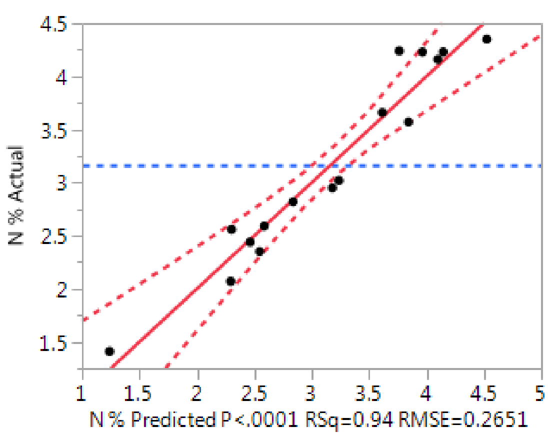
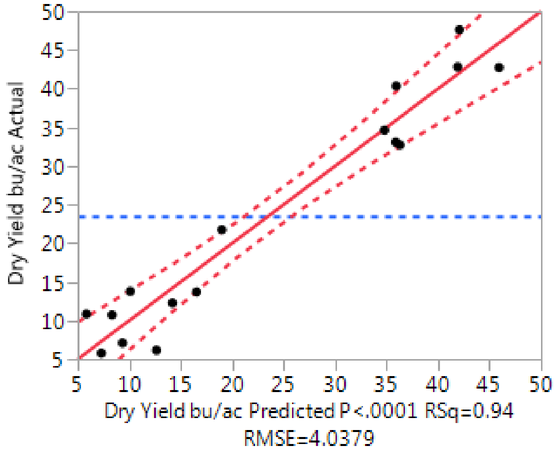


Figure 2. Colorspace histogram examples for Plot 101 (a) and Plot 102 (b).



Parameter Estimates				
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	8.0633228	0.442083	18.24	<.0001*
R13_fraction	-16.7593	2.750602	-6.09	0.0001*
R14_fraction	-10.95771	2.748274	-3.99	0.0026*
R17_fraction	-28.86088	4.521609	-6.38	<.0001*
B3_fraction	-9.867999	1.422574	-6.94	<.0001*
B10_fraction	52.148915	13.81751	3.77	0.0036*

Figure 3. Actual vs. predicted leaf nitrogen, predicted from digitized aerial image data collected at the time of leaf tissue sampling.



Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	22.09895	4.532628	4.88	0.0004*
R10_fraction	175.3401	25.3791	6.91	<.0001*
R18_fraction	-140.392	28.1218	-4.99	0.0003*
B9_fraction	67.486679	25.01895	2.70	0.0194*

Figure 4. Actual vs. predicted yield, predicted from digitized aerial image data collected at the time of leaf tissue sampling.

Prior to submission, reports should be saved as a pdf document using the following naming convention; 2019Date(yrmoday)_(PI Last Name)_(Abbreviated Proposal Title)_Final.