PROGRESS REPORT

PROJECT TITLE: Phenomics tools for corn breeding and management decisions
PROJECT NUMBER: 4154-1SPX
REPORTING PERIOD: 07/01/19-09/30/19
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1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD.

Objective 1: Develop crop models using UAS imagery in homogenous fields containing plots with variable genetic material and management practices

We continued to collect weekly UAS imagery throughout the growing season until plants reached their terminal height after flowering. Using our newly finalized image extraction pipeline (Figure 1), we have extracted trait values for all of our flight images that were taken of St Paul trial plots during summer 2020.

We also obtained images of a production field throughout the season and have begun to apply our image extraction methods to these flights to determine the accuracy of trait values extracted from the images relative to hand measurements obtained in the same field. Preliminary analyses have identified a number of complexities that result from differences in the field layout (i.e. plots with plants and allies, versus continues plants) that we are currently working to address.

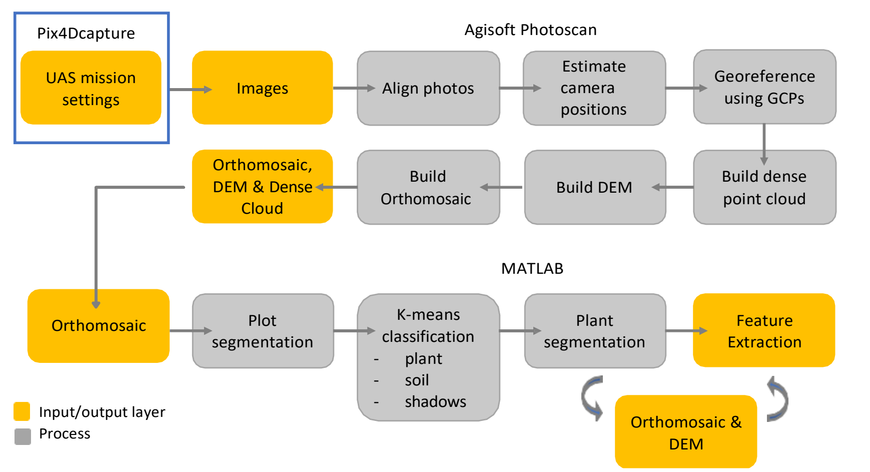

Figure 1. UAS image acquisition and extraction methodology.

With help from Paul Meints, we have identified four growers who are willing to allow us to conduct flights in their production fields in summer 2020. We will also be sampling grain from plants within a few coordinates of these fields to obtain yield values which can be compared to our predictions obtained from early season growth rate data. The modifications we are currently implementing to the analysis pipeline will be applied to extract data from this future UAS imagery.

Objective 2: Identify spectral wavelengths and morphological features that differentiate stress response.

We have continued running greenhouse experiments to determine optimized growth conditions to achieve maximum morphological and spectral differentiation of stress versus control conditions. We are seeing a strong response from our cold stress treatment (Figure 2), and are now testing for repeatability of the stress response within and across genotypes.

Figure 2. Demonstration of effective stress treatment (right) versus control plant (left).

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.

We flew and imaged a trial with 24 hybrids planted in replicate under two dates and three planting densities in St. Paul, MN (Figure 3). The field was imaged weekly after planting using a DJI Phantom 4 Advanced drone. Using the procedure described above, we extracted plant height data from each of the plots throughout the growing season. We were able to detect significant biological variation in growth patterns and responsiveness to growth conditions throughout the growing season for the hybrid genotypes that were included in this experiment. Figure 4 shows an example of the difference between two of the genotypes across the three planting densities (60,000 plants/ha, 80,000 plants/ha, and 120,000 plants/ha). Early in the season the growth patterns of these two genotypes were very similar at the low and medium density. At the high density LH82 x LH145 grew at a faster rate early in the season as compared to LH82 x DK3IIH6, and reached its terminal height more quickly than it did at the low and medium planting densities. Understanding growth patterns of different genotypes can be very informative in identifying superior genotypes to avoid key points of potential stress (i.e. early season cold, etc.) throughout the growing season.

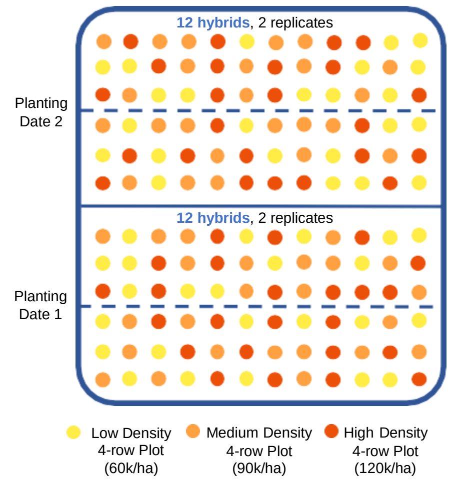

Figure 3. Field trial experimental design

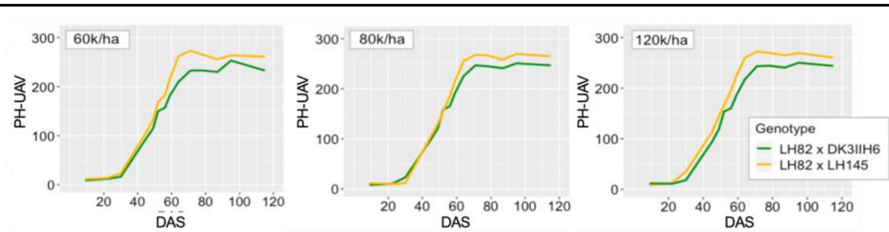

Figure 4. Height through time as measured by the UAV for plots of two different genotypes in the late planting date treatment and the low, medium, and high planting densities.

As described in the previous quarterly report, we have had extreme windstorms on the St. Paul farm during many of the recent growing seasons. These events provide us with the opportunity to study variation in lodging among experimental units. This variation can be driven by genotype, environmental conditions before the event, and management practices, or random variation, and we can test to determine how much each of these factors contributes to the observed variation. Figure 5 shows plots immediately following one of these windstorms (top left image) and a few days later after plants have recovered (top right image). Using drone imagery we are able to take daily height measurements for these plots and capture variation in both the initial event and variation in the post-lodging recovery. To evaluate lodging severity we calculated the percent change in height from the values obtained two days before the windstorm and the day after the storm. A negative value is indicative of a plot that has become shorter due to lodging and a positive value reflects plant growth over that three day period of time, and minimal if any lodging. Across the two planting dates we saw substantial difference in lodging severity. The earlier planting date, which was at a later developmental stage, showed substantially more lodging (Figure 5). We have also been able to track recovery of plots with daily flights following the initial lodging event. The speed at which these data can be collected are scalable to the size of a commercial breeding program and would allow breeders to have data for line selection that is typically not available.

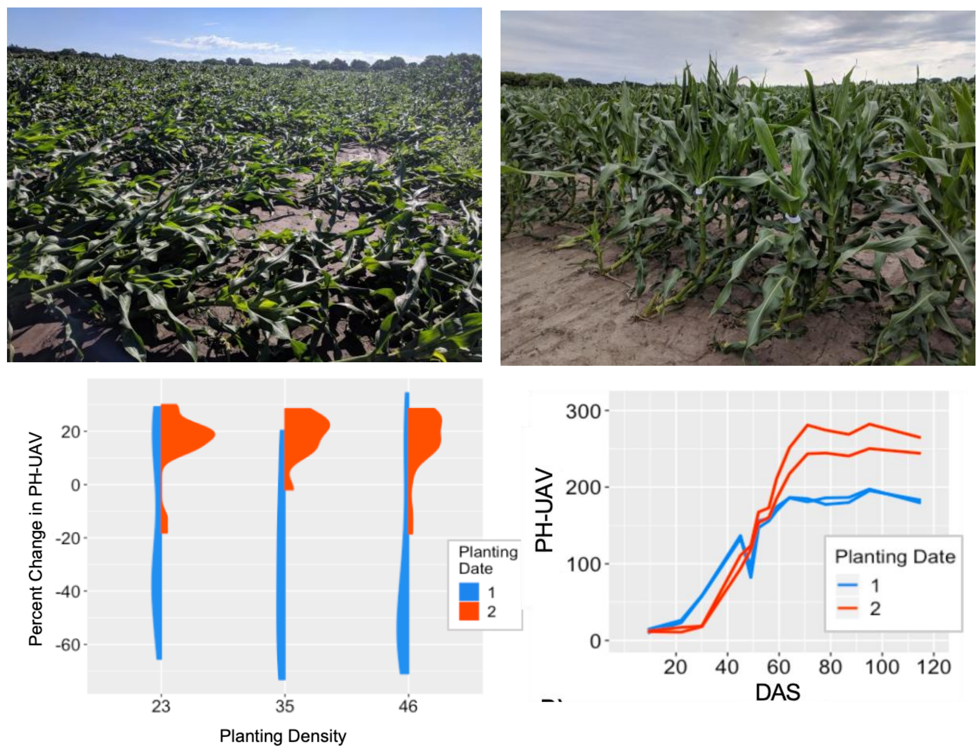

Figure 5. Percent change in UAV mean plot height for all plots across both planting dates (left) and post lodging recovery (right).

We were interested to determine if we could predict end season trait values (i.e. plant height) from values measured earlier in the season. As has been demonstrated in other previous work from our group and others, we saw very little correlation between trait values early in the season and trait values at maturity. However, when the rate of change between time points rather than the values at each time point per se are used, the correlation between early season trait values and trait value at maturity become much stronger. We hypothesize that the reason for this is that growth rate is more indicative of environmental responsiveness of the genotype and as such is better at predicting the value of a trait after an entire season of plants interacting with and responding to their environment. We are beginning to test the ability to use early season trait values and growth rate estimates in models that predict more complex traits at maturity such as yield.

3.) CHALLENGES ENCOUNTERED.

No new challenges have been encountered during this quarterly reporting period.

4.) FINANCIAL INFORMATION

No budgetary challenges were encountered and there were no significant deviations from the projected project spending.

5.) EDUCATION AND OUTREACH ACTIVITES.

Manuscript submitted for peer review and available in pre-print:

Tirado, S., **C. Hirsch**, N. Springer. 2019. UAV Based Imaging Platform for Monitoring Maize Growth Throughout Development. bioRxiv.doi.org/10.1101/794057. (*under review at Plant Direct*)
Available at https://www.biorxiv.org/content/10.1101/794057v1

Invited Talk:

Hirsch, C. 2019. Multidisciplinary Approaches to Solve Questions in Maize Genetics and Breeding. University of Illinois Urbana-Champaign Corteva Plant Sciences Symposium. October 4.