High-Throughput Phenotyping that Improves the Efficiency of a Cotton Plant Breeding System

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Abstract

Unmanned aerial vehicles (UAV) can become important tools for cotton breeders which facilitate high-throughput phenotyping (HTP). In order to capture a three-dimensional view of field plots, sensors mounted on UAV's must have access to a view of the nearby soil level, but cotton planted in solid rows can obscure this image. The research objectives of this project were to 1) evaluate the ability of UAVs to predict plant height and yield; 2) determine if there are genotype X row-spacing effects that would change the decision making process of a cotton plant breeder. Five cotton genotypes were grown in a skip versus solid row-pattern at three locations in 2017 and 2018. Yield and fiber qualities were measured for all treatments. A quad-copter UAV was flown across the field to estimate boll numbers just prior to harvest. There were no genotype X row-spacing effects for any fiber traits at any location. Genotype X row-spacing effects were minimal for lint yield. Yield estimations were improved when the UAV could capture a three-dimensional view of the plot. Therefore, when using a UAV for HTP, cotton should be grown in a skip-row configuration.

Introduction

In recent decades, genotyping capabilities have begun to out-pace phenotyping capabilities in terms of speed and accuracy. In an effort to close this gap, research teams at Texas A&M University have begun using unmanned aerial vehicles carrying various sensors to monitor large numbers of breeding lines through-out the growing season. A confounding issue that cotton breeders have encountered is canopy closure during mid-growing season, which prohibits sensors from measuring plant architecture and boll-loads 3-dimensionally. A project was initiated in 2017 that compared solid vs. skip-row patterns in terms of predicting yield and fiber quality because a skip-row pattern would allow UAV sensors to capture 3-dimensional data from plots.

Hypotheses:

- UAV can accurately predict plant height and yield.
- Row-spacing (solid vs. skip-row) has no effect upon lint yield or fiber quality.

Methods

Trial locations: Weslaco (irrigated); Corpus Christi (dryland); College Station (irrigated and dryland)

Genotypes: 'Tamcot 73' (early maturing variety); ' Tamcot 211' (okra-leaf); 'Tamcot 421' (mid-maturity); 'TAM exp. T-08' (full-season; high quality fiber); 'TAM exp. X-26-3' (drought tolerant; high quality fiber)

Row spacing: Weslaco (96 cm vs 192 cm); Corpus Christi (96 cm vs 192 cm); College Station (102 cm vs 206 cm)

Trial design: Split-plot design (row-spacing as main treatment; genotypes as sub-treatment); four replications

Harvesting: Seed cotton harvested with a mechanical plot picker harvester. 30-boll samples used to estimate lint % and fiber traits

UAV: 'DJI Matrice 100'; RGB – DJI Phantom 4 Pro;

Manual Data Collection:

College Station

Fly the UAV bi-weekly basis

Ground truth data:

- Plant height (mid season)
- NAWF (3 times in mid- to late-season)
- Boll count per meter just prior to harvest

Corpus Christi

Fly the UAV bi-weekly basis

Ground truth data :

- Plant height (early- to mid-season)
- Boll count per meter just prior to harvest

Results and Discussion

The ability of UAVs to predict plant height and yield

- UAV has the ability to predict plant height.
- UAV data from skip row is more accurate than solid row

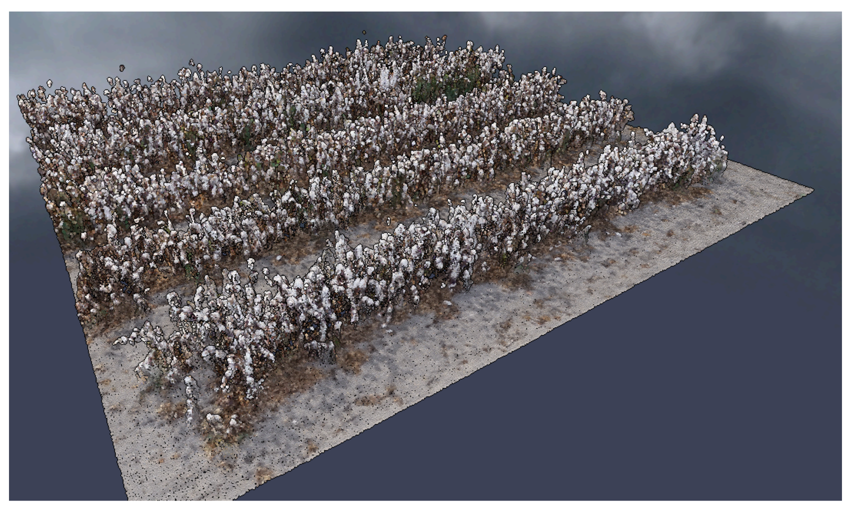
Solid versus Skip-Row

- Under normal conditions, interactions are minimal
- Breeding progress is likely not affected by row spacing
- Fiber traits are not affected by row-spacing

<Digital Surface Model>

<Digital Elevation Model>

<Plant Height Model>



<3D Point Cloud>

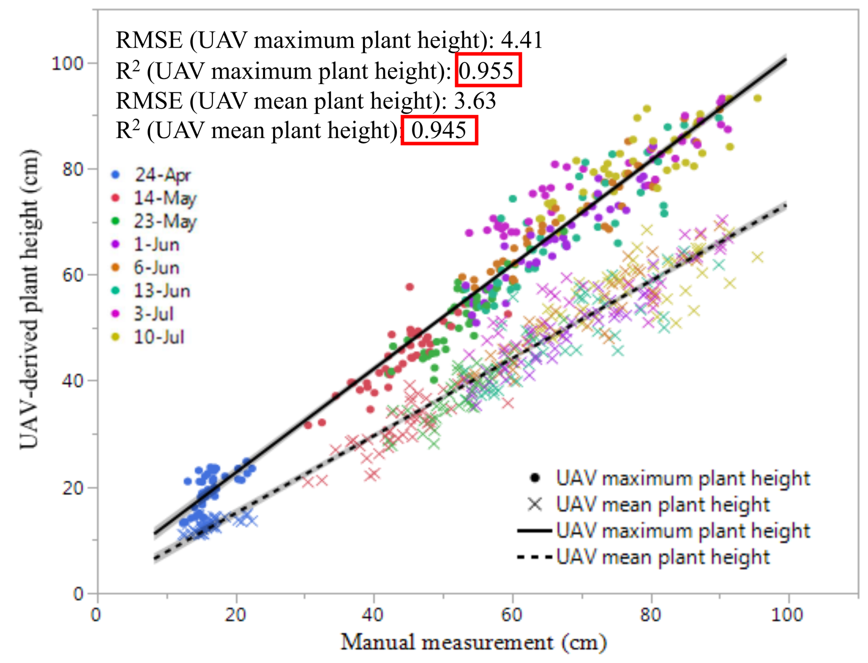


Figure 1. Correlation between UAV-based plant height and manual ground measurements for plant height at Corpus Christi, TX, in 2018.

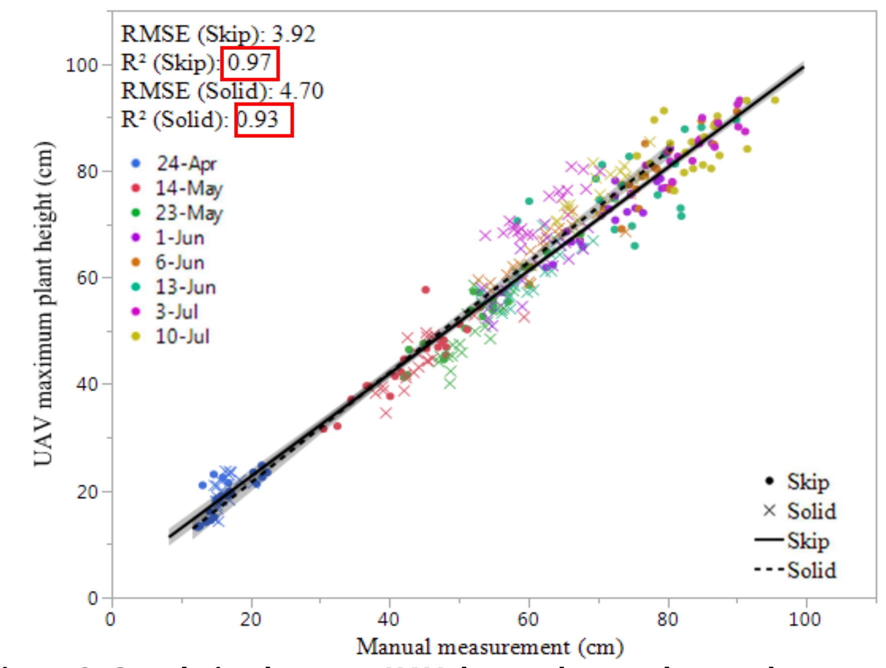


Figure 2. Correlation between UAV data and manual ground measurements for plant height at Corpus Christi, TX, in 2018 (skip row).

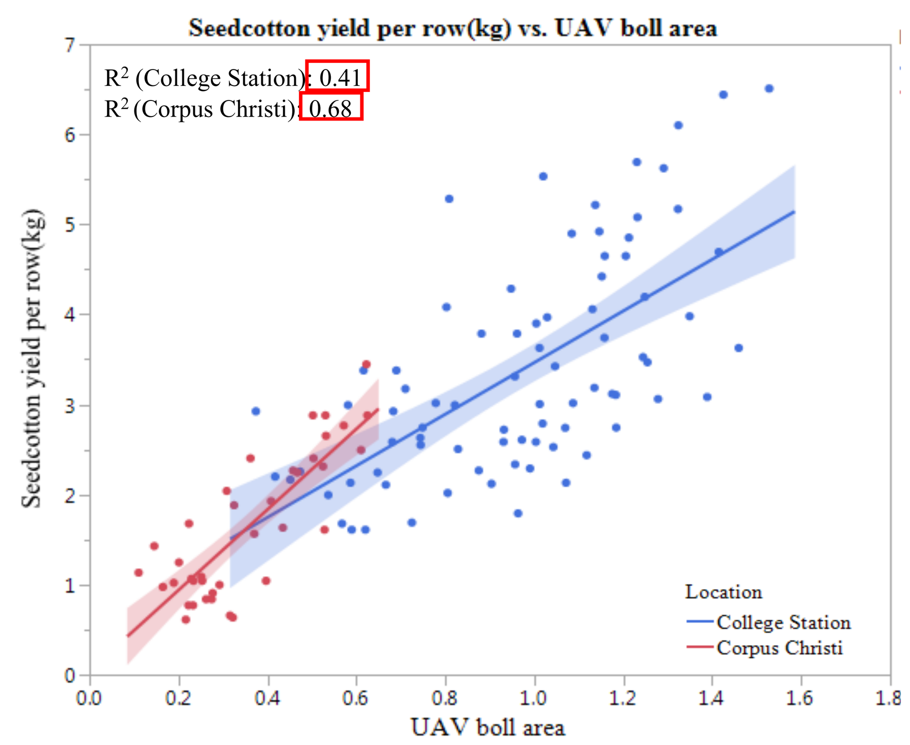


Figure 3. Correlation between UAV-based boll area measurement and Yield per row at Corpus Christi and College Station, TX, in 2018

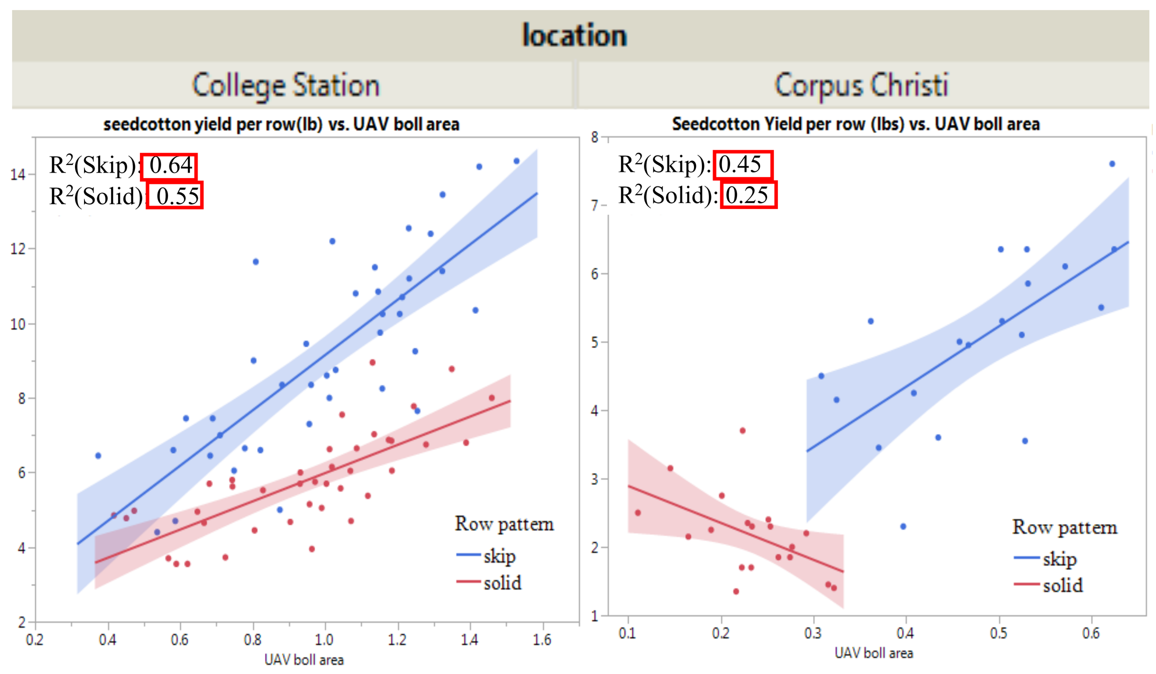


Figure 4. Figure 9. Correlation between UAV based-boll area from different planting pattern and Yield per row at College Station and Corpus Christi, TX in 2018

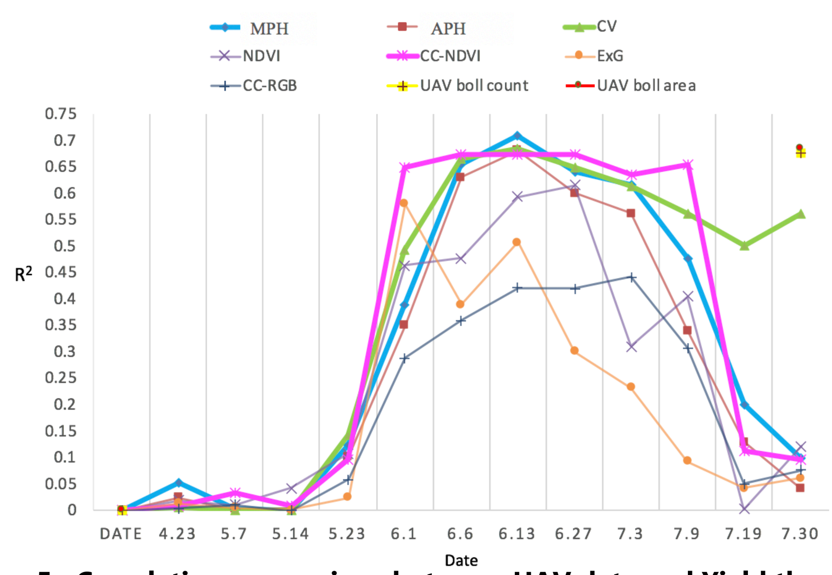


Figure 5. Correlation comparison between UAV data and Yield throughout whole growing season

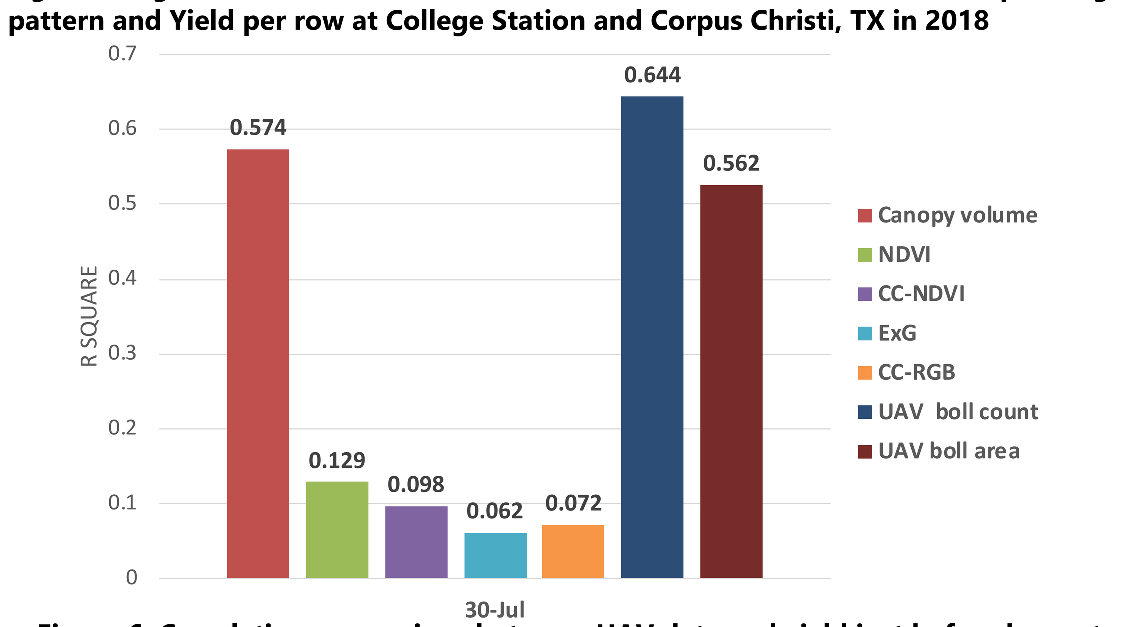
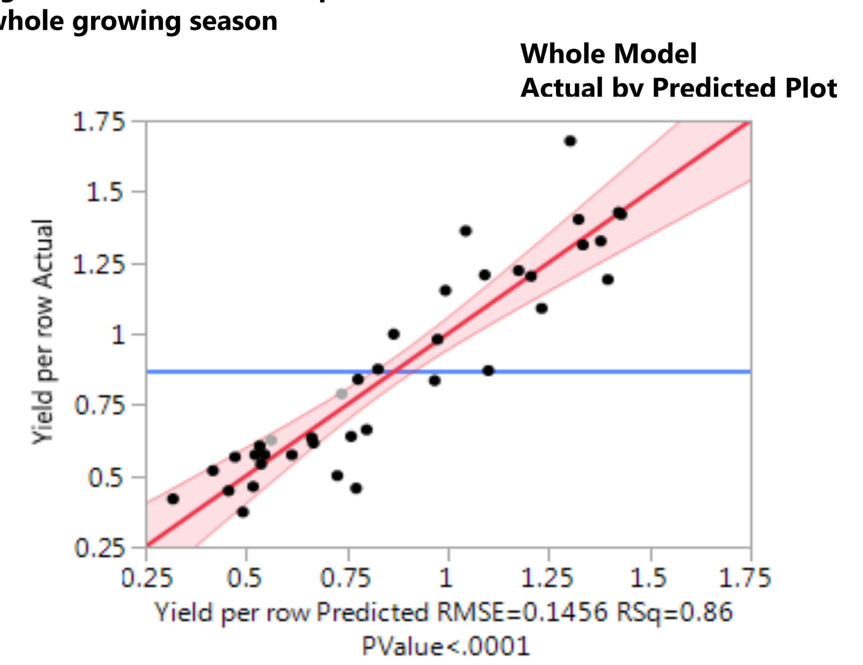


Figure 6. Correlation comparison between UAV data and yield just before harvest



Run stepwise to find best yield predictors combination

Summary of Fit

R Square	0.856
R Square Adj	0.838

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.884	0.768	3.75	0.0007*
CV 05/14	-5.567	1.071	-5.20	<.0001*
CV 06/13	4.645	0.549	8.46	<.0001*
NDVI 07/19	-3.812	1.213	-3.14	0.0035*
UAV boll area	-0.746	0.349	-2.14	0.0401*

Table 1. ANOVA of Genotype X Row Pattern

Trait	CollSt dryland 2018	CorpCh 2018	Weslaco 2018	CollSt Irrigated 2018	CollSt 2017	CorpCh 2017	Weslaco 2017
Lint %	ns	ns	ns	ns	ns	ns	ns
Lint yield	ns	ns	ns	ns	***	ns	ns
Fiber traits							
Micronaire	*	ns	ns	*	ns	ns	ns
Length	ns	ns	ns	ns	ns	ns	ns
Uniformity	ns	ns	ns	ns	ns	ns	ns
Strength	ns	ns	ns	ns	ns	ns	ns
Elongation	ns	ns	*	ns	ns	ns	ns

Conclusion

To take full advantage of UAV data, cotton breeding programs need to plant early generation lines (progeny rows) in skip rows that allow sensors to reach the soil level and capture 3-D images. This can be done without compromising the efficiency and accuracy of the breeding program.