ANALYSIS OF PLANT GROWTH AND YIELD USING AN UAS (UNMANNED AIRCRAFT SYSTEM)-BASED REMOTE SENSING PLATFORM

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Abstract

Currently, there is a need to advance data collection and processing capabilities in support of agriculture research and plant breeding. An Unmanned Aerial Vehicle (UAV)-based high throughput phenotyping system was developed at Texas A&M AgriLife and Texas A&M University – Corpus Christi to enable high quality data collection at spatial and temporal scales previously unobtainable at a reasonable cost. A field test consisting of twenty-five advanced genotype entries from Texas A&M AgriLife research breeding programs and five commercial checks was established in 2016. Plots were two rows wide by 10m long, replicated four times, and grown under rain-fed conditions following typical practices for the region. Plots were monitored using a DJI Phantom 3 UAV platform and its standard red-green-blue sensor. Growth and growth rate curves were developed for plant height, canopy cover, and canopy volume traits, as estimated by UAS data. Thirteen parameters for each trait were derived from growth and growth rate curves and used to characterize best-performing genotypes. Plant height data (and its derived variables) indicated that, under the conditions tested, genotypes exhibiting early plant development with gradual slowdown outperformed others. The data analysis procedure briefly discussed here demonstrates the feasibility and capability of using UAV-based platforms, combined with data processing software to extract plant growth data capable of describing the temporal development and yield response of a crop.

Introduction

An UAS-based high throughput phenotyping system for cotton was developed by Texas A&M AgriLife and Texas A&M University, Corpus Christi, TX. The system includes an automated data processing workflow for UAS data collected over the growing season, to extract various phenotypic features such as plant height, canopy cover, canopy volume, bloom count, open boll count, vegetation indices, and canopy surface temperature. In addition, growth analysis was performed by fitting non-linear models to the UAS-derived phenotypic features to represent temporal variation of cotton genotypes' responses. The growth analysis provides the following information for each experimental unit: (1) growth rate related parameters such as maximum growth rate, timing of the maximum growth rate, duration and timing of the half maximum growth rate, increasing slope of growth rate in early season, and decreasing slope of growth rate in late season, and (2) canopy efficiency related parameters such as the maximum normalized difference vegetation index (NDVI) or Excessive Greenness Index (E×G), timing of the maximum NDVI and E×G, increasing slope of NDVI and E×G in early season, and decreasing slope of NDVI and E×G in late season.

Objectives

The objectives in this report are to demonstrate the potential benefits of using UAV platforms for the collection of temporal plant growth data for high-throughput phenotyping, and cultivar evaluation/selection.

Materials and Methods

A cultivar evaluation test established at the Texas A&M AgriLife Center (Corpus Christi, TX) in 2016 was selected for this study. The test consisted of twenty-five advanced genotype entries with five commercial checks, replicated four times. Planting date was April 1st, 2016 (emergence date was defined as April 10th, 2016). This experiment was conducted under rain-fed conditions using tillage and fertility practices typical for crops produced in the region. Plots were monitored weekly using a DJI Phantom 3 quadcopter, equipped with a gimbal-stabilized RGB camera. Processing of RGB images, for each entry, led to the development of growth and growth rate curves for plant height, canopy cover (shown in figure 1), and canopy volume.

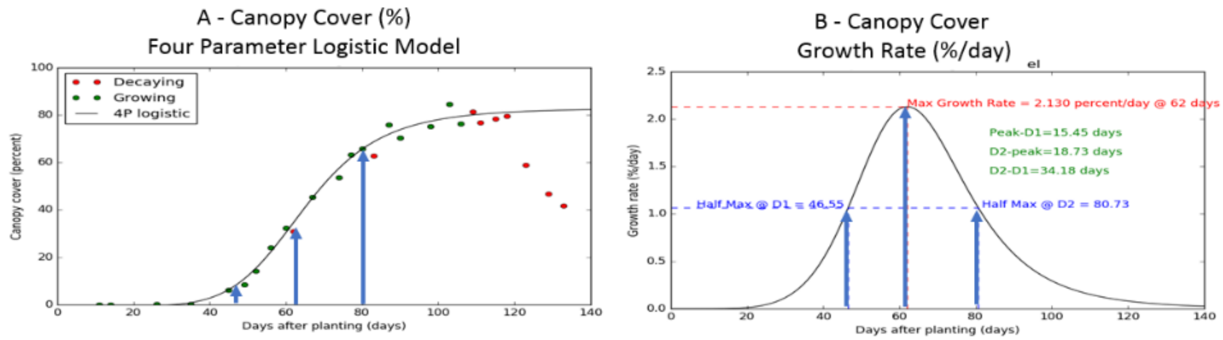

Figure 1. Example time course of canopy cover development (A) and growth rate (B) for Phytogen 499 WRF derived from Unmanned Aerial System data. Corpus Christi, TX, 2016.

Results and Discussion

Plant growth and growth rate response curves displayed in figure 1 enabled the extraction of additional growth and rate parameters to characterize the performance of each genotype entry. Thirteen parameters were extracted for each trait (plant height, canopy cover, and canopy volume) for a total of thirty-nine parameters (table 1).

Table 1 shows that 6 of 13 parameters extracted from plant height curves were significantly correlated with machine harvested seedcotton yield. Figure 2 demonstrates plant height parameters that were significantly correlated with seedcotton yield. For the purpose of this report, we limited our discussion to plant height development. Future analysis of this data would include canopy cover, canopy volume, and canopy efficiency related.

Parameters 2, 4, and 6 were negatively correlated with yield indicating that early expression of these events should be advantageous to cultivars in maximizing seedcotton yield under dryland conditions. This also suggests that earliness, under the conditions tested was an important trait of successful genotypes. Parameters 9 and 13, which were positively correlated with yield, seem to indicate that the capacity of a cultivar to maintain half of maximum growth rate for a longer period of time should result in higher cottonseed yield. Parameter 11, the relative growth rate, expressed as a % of Maximum growth was negatively related to yield indicating that the slowest decline in late season growth rate should also result in higher productivity. In other words, the dataset shown here indicates that during 2016, under rain-fed conditions at Corpus Christi, TX, genotypes that were able to quickly develop (both in height and canopy cover) had better yield performance. Not only that, but the data also suggests that a gradual slowdown of crop development is also beneficial. In summary, the best performing genotypes under the conditions tested exhibited earliness as one of the main characteristics, as well as a good 'plant frame' to support the transition into reproductive growth.

Conclusions

The data analysis procedure briefly discussed here demonstrates the feasibility and capability of using UAV-based platforms, combined with data processing software, to extract plant growth data capable of describing the temporal development and yield response of a crop. Information generated by this UAV system should be valuable to breeders in selecting or designing genotypes for a given environment. It can be beneficial to cotton agronomists, consultants, and producers in selecting cultivars with desirable traits for a particular production system. Our goal is to use the large volume of plant growth data generated by this platform to develop "expert systems" to automatically sort and analyze the information, identifying the most promising genotypes for a giving location or production system.

Table 1. Description, correlation coefficients, and significance for growth and rate parameters extracted from plant height, canopy cover, and canopy volume curves with seedcotton yield. **Significant at 0.05. ***Significant at 0.01.

	Parameter Number	Description	Correlation	Sig.
Plant Height	1	Maximum growth rate	-0.04	
	2	Maximum growth, date	-0.52	***
	3	Half maximum rate (early)	-0.04	
	4	Half maximum, date (early)	-0.57	***
	5	Half maximum rate (late)	-0.04	
	6	Half maximum, date (late)	-0.44	**
	7	Duration maximum growth rate	0.40	**
	8	Duration early half maximum rate	0.34	
	9	Duration Late half maximum rate	0.42	**
	10	Relative growth rate, early	-0.26	
	11	Relative growth rate, late	-0.43	**
	12	Early growth rate area	0.34	
	13	Late growth rate area	0.39	
Canopy Cover	14	Maximum growth rate	-0.03	
	15	Maximum growth, date	-0.44	**
	16	Half maximum rate (early)	-0.03	
	17	Half maximum, date (early)	-0.56	***
	18	Half maximum rate (late)	-0.03	
	19	Half maximum, date (late)	-0.36	**
	20	Duration maximum growth rate	0.05	
	21	Duration early half maximum rate	-0.09	
	22	Duration Late half maximum rate	0.26	
	23	Relative growth rate, early	-0.03	
	24	Relative growth rate, late	-0.30	
	25	Early growth rate area	-0.10	
	26	Late growth rate area	0.35	**
Canopy Volume	27	Maximum growth rate	0.18	
	28	Maximum growth, date	-0.55	***
	29	Half maximum rate (early)	0.18	
	30	Half maximum, date (early)	-0.57	***
	31	Half maximum rate (late)	0.18	
	32	Half maximum, date (late)	-0.50	***
	33	Duration maximum growth rate	0.44	**
	34	Duration early half maximum rate	0.34	
	35	Duration Late half maximum rate	0.47	**
	36	Relative growth rate, early	-0.32	
	37	Relative growth rate, late	-0.49	**
	38	Early growth rate area	0.41	**
	39	Late growth rate area	0.52	***

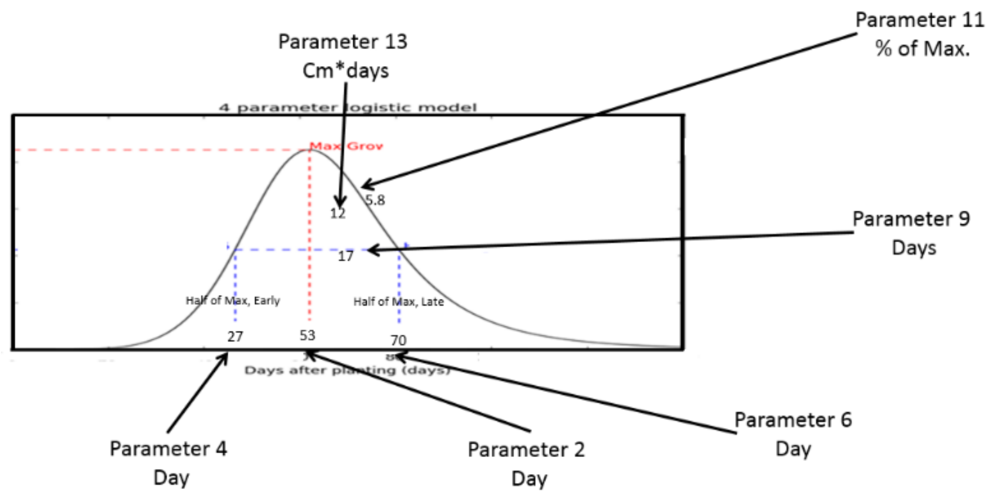

Figure 2. Plant height growth characteristics of average 20% higher yielding entries shown in cm day^{-1}.