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Final Research Report

I. Abstract

Project Title: "Can UAV technology be used for peanut variety selection?"

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Principal Investigators:

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Summary: This work was aimed at validating drone technology use for improving and expediting breeding selection for drought tolerance in peanut. Drought stress was imposed by covering the plots with two rainout shelters staring at beginning pegging. In the same field set up, well watered plots were replicated next to water stressed plots also replicated under the shelters. Weekly measurements of normalized difference vegetation index (NDVI) and canopy temperature differential (CT) were taken. On Aug 3 and 10 at 15 and21 days after water stress imposition wilting was rated visually and pictures of individual plots were taken. After harvest, pod yield, Sound Mature Kernel (SMK) content and Crop Value were determined. Data show strong relationship between the agronomic traits and vegetation indices determined as CT, NDVI, and from RGB pictures. These denotes that both ground and aerial indices can be used to predict peanut performance under a range of soil water regimes. However, more research is needed to identify which indices or combination of them can be used for verity selection.

II. Main Body of Report

Project Title: "Can UAV technology be used for peanut variety selection?"

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Objectives: We hypothesized that field evaluation using drone technological advances (digital, NIR, and IR high resolution cameras; images taken at 3 to 10 m above the plots for high resolution pictures; a hundred plus plots evaluated at the same time and within 5 to 10 minutes from each camera shot) has improved screening resolution over the ground equipment currently used by breeding programs. Therefore our objective was to identify suitable digital, NIR and IR indices taken by an unmanned aerial vehicle (UAV) for selection of peanut varieties with improved yield. We also anticipated that finding key growth stages and best measures for stress detection could be related to the use of these technologies for on-farm applications as well.

Procedures: Twenty three peanut varieties genetically diverse for yield and water use based on preliminary research (Balota et al., 2012; International Peanut Genome Initiative, 2014) were used. Varieties, cultivars and breeding lines, names and yield under the two water regimes are presented in Table 1.
Varieties were planted on May 2 in a factorial design using two rain exclusion shelters (23 m long by 9 m wide by 3.7 m tall) (Atlas Manufacturing, GA); varieties were replicated twice under each shelter (four total replications) for deficit irrigation. These plots only received a survival rate of 1.5-inch irrigation on Aug 18. Next to the rain shelters, the same varieties were planted for a well watered irrigation regime. Well watered plots were irrigated twice on Aug 10 and 24 with a total of 3 inches water. It was no need for more irrigation because, excepting the mid- to later part of August when we irrigated, precipitation was abundant through the rest of the growing season.
Plot size was 1.8 m long by 0.9 m wide. Irrigation was achieved through a lateral pull boom cart sprinkler irrigation system (E1025 Reel Rain, Amadas Ind., Suffolk, VA) built to accommodate irrigation under the rain shelters. At beginning pegging growth stage (R2) (Boote, 1987) on July 19, shelters were pooled over the plants and soil water

was continuously monitored at 15 to 76 cm depth by EC-5 soil moisture sensors (Decagon Devices Inc., Pullman, WA) within each shelter. Shelter was maintained over the plots until full seed stage (R6), on Aug 29.
From July 19 through Sep 8, weekly measurements were taken on the ground on canopy temperature differential (CT) (calculated as canopy minus air temperature; negative values denoting cooler, healthier plants and positive values denoting water stressed plants) with a handheld AGRI-THERM III IR thermometer (Everest Interscience, AZ); and normalized difference vegetation index (NDVI) (a measure of leaf greenness and plant biomass; higher values denoting greener and bigger plants) with a Trimble GreenSeeker handheld crop reflectance sensor. NDVI was always measured at 11:00 AM to noon; CT was measured at 9:00 AM, 11:00 AM; 1:00 PM, and 3:00 PM. On Aug 3 and 10, when plants showed visible stress symptoms all plots were rated visually for wilting; on Aug 10 they were rated in the morning and in the afternoon. Digital pictures were also taken on the ground with a Samsung NX300 camera and RGB indices calculated on Aug 3 and 10, in the morning and in the afternoon. These measurements continued after shelters' removal on weekly basis so we can see the recovery of the varieties from water stress from a rain event of 3 inches on Sep 2 and 3.
After shelters' removal CTD, RGB, and NDVI measurements were taken daily with a drone flying at 20 and 30 feet above the plots. Here we only report the data from Aug 29 and 30, as the rest of aerial data is still being processed.
Yield and grading characteristics were measured after harvest of all plots with a stationary picker on Oct 13.

Results and Discussion:
Significant differences among water regimes were observed, with well watered plots producing in average 5,362 lb/A and water stressed plots only 3,618 lb/A (Table 1). Significant differences among varieties for yield existed under both water regimes, but they were greater under drought. Under well water regime the greatest yielding was line 08X09-3-14-1 (7,841 lb/A0 and the least yielding was an unimproved hirsute-type line from Mexico, SSD6 (2,178 lb/A). The greatest yielding varieties under drought were TUFRunner 297 and C76-16, both with 4,966 lb/A, followed by Sugg, Florunner, GP-NC WS 17, TifRunner, GP-VT NC 01, Georgia 09B, and FloRun 107, all with yields exceeding 4,000 lb/A under drought. Bailey, Emery, Sullivan and Wynne produced less under drought.
There were significant effects of variety and water regime for all field measurements, CT, NDVI, RGB, and visual wilting, taken prior to harvest. These indices estimated reasonably well yield, Sound Mature Kernel (SMK) content, Value, and plant wilting indicating that they could predict yield and the other agronomic traits with confidence. For example, Tables 2-4 show the correlation coefficients of the ground and aerial NDVI, CT and RGB; regardless the sign, the higher the numbers in these tables the better wilting, pod yield, SMK, and Value were predicted. Wilting, which is a common water stress symptom, was best estimated by NDVI and RGB, and least by CT; but CT was best in estimating yield, SMK and Value in particular when taken on the ground at 15 days after covering the plots under the water stress regime. Interestingly, CT predicted well plant wilting even before it occurred, i.e., correlation coefficients are negative and over 0.750 when CT was measured on July 19 and 20 even though wilting was visible only after two weeks. After three weeks of no additional water, the relationship between CT and wilting became positive (positive correlation coefficients) showing that hotter plants (higher CT values) were more visibly wilted and stressed than cooler plants. This suggests that varieties that were cooler and transpired more early on, they used soil moisture faster and wilted more later. This could be a mechanism of drought tolerance and it could be used by breeders to further improve drought tolerance of peanut in the region.

Discoveries: We noticed line 08X09-3-14-1 with superior pod yield under both water regimes. This is an advanced breeding line from the University of Florida's breeding program with the high oleic characteristic. This line was tested for two years in PVQE trials across the VC region and showed high yields when compared with other lines in the test and Bailey. If after additional years of testing in PVQE trials and under the rainout shelter the results are similar with those here, this line could become a serious candidate for commercial release as a drought tolerant line for the VC region. We are preparing a paper with this information to be presented at a national meeting this spring.

Table 1. Pod yield of 23 peanut varieties affected by two water regimes in a rainout shelter test in Suffolk, VA, in 2016.

Variety	Well-watered regime	Drought regime
	Pounds per acre	
08X09-3-14-1	7,841.00	3,964.00
Bailey	4,312.50	3,049.25
C76-16	7,231.00	4,966.00
Emery	5,968.00	3,223.50
FloRun107	6,621.00	4,072.75
Florida-07	5,967.50	3,310.50
Florunner	5,619.50	4,769.75
GP-NC WS 16	6,098.50	3,811.75
GP-NC WS 17	5,881.00	4,530.00
GP-VT NC 01	6,359.50	4,181.75
Ga09B	5,837.00	4,116.25
N04074FCT	4,225.50	1,480.75
N08082olJCT	5,096.50	3,463.00
NC3033	3,790.00	1,938.50
NMValencia	3,441.00	2,722.50
Olin	4,443.00	3,092.75
SSD6	2,178.00	1,036.75
Sugg	5,749.50	4,835.00
Sullivan	4,878.50	3,833.25
TR297	6,098.50	4,965.75
TR511	6,011.00	3,985.75
TifRunner	4,878.50	4,443.00
Wynne	4,791.50	3,419.50
Mean	**5,361.65**	**3,617.91**
Probability	*0.0001*	*0.028*

Table 2. Correlation coefficients (r) from a Pearson correlation matrix between ground and aerial-taken NDVI, and visual wilting score, pod yield, sound mature percent, and crop value evaluated at several dates after imposition of two water regimes. Twenty three peanut genotypes were grown under well-watered and water withholding conditions (n = 46) in the field under rainout shelters at the Tidewater AREC in Suffolk, VA, in 2016

	Ground NDVI July 20	Ground NDVI July 27	Ground NDVI Aug 3	Ground NDVI Aug 10	Ground NDVI Aug 16	Ground NDVI Aug 18	Ground NDVI Aug 23	Aerial* NDVI Aug 30	Ground NDVI Aug 30	Ground NDVI Sep 1	Ground NDVI Sep 6	Ground NDVI Sep 8
Visual wilting; Aug 3 @ 15:00	0.267	0.204	-0.227	-0.581	-0.350	-0.726	-0.827	-0.785	-0.831	-0.228	-0.558	-0.643
Visual wilting Aug 10 @ 9:00	0.350	0.225	-0.134	-0.237	-0.333	-0.624	-0.658	-0.742	-0.626	-0.283	-0.259	-0.323
Visual wilting Aug 10 @ 15:00	0.249	0.258	-0.204	-0.255	-0.226	-0.609	-0.615	-0.725	-0.636	-0.342	-0.232	-0.348
Pod yield	-0.012	-0.264	0.401	0.466	0.551	0.617	0.615	0.538	0.574	0.276	0.296	0.299
Sound Mature Kernels	-0.087	-0.324	0.360	0.154	0.434	0.457	0.440	0.468	0.378	0.226	0.096	0.202
Crop Value	-0.019	-0.249	0.430	0.417	0.550	0.632	0.615	0.524	0.572	0.249	0.259	0.311

*Correlation coefficient between ground and aerial NDVI on Aug 30 was 0.800.

Table 3. Correlation coefficients (r) from a Pearson correlation matrix between ground and aerial-taken canopy temperature differential (CT), and visual wilting score, pod yield, sound mature kernel percent, and crop value evaluated at several dates after imposition of two water regimes. Twenty three peanut genotypes were grown under well watered and water withholding conditions (n = 46) in the field under rainout shelters at the Tidewater AREC in Suffolk, VA, in 2016. Within each date only the hours of measurement showing the highest correlation with the agronomic traits are presented; and they are indicated in the table

	Ground CT July 19 @ 11:00	Ground CT July 20 @ 11:00	Ground CT July 27 @ 11:00	Ground CT Aug 3 @ 15:00	Ground CT Aug 10 @ 13:00	Ground CT Aug 16 @ 15:00	Ground CT Aug 18 @ 15:00	Ground CT Aug 23 @ 15:00	Aerial* CT Aug 30 @ 15:00	Ground CT Aug 30 @ 9:00	Ground CT Sep 1 @ 15:00	Ground CT Sep 6 @ 13:00	Ground CT Sep 8 @ 11:00
Visual wilting; Aug 3 @ 15:00	-0.753	-0.729	-0.582	0.742	0.701	0.787	0.723	0.702	0.636	0.767	0.765	0.735	-0.650
Visual wilting Aug 10 @ 9:00	-0.823	-0.750	-0.653	0.891	0.821	0.906	0.878	0.792	0.599	0.860	0.793	0.837	-0.754
Visual wilting Aug 10 @ 15:00	-0.837	-0.772	0.694	0.881	0.805	0.885	0.863	0.751	0.612	0.900	0.799	0.859	-0.696
Pod yield	0.517	0.560	0.468	-0.558	-0.517	-0.584	-0.547	-0.532	-0.507	-0.679	-0.594	-0.640	0.537
Sound Mature Kernel	0.770	0.690	0.670	-0.731	-0.681	-0.716	-0.741	0.627	0.521	-0.822	-0.706	-0.738	0.796
Crop value	0.623	0.642	0.587	-0.628	-0.572	-0.649	-0.634	-0.577	-0.513	-0.769	-0.688	-0.721	0.655

*Correlation coefficient between ground and aerial CT on Aug 30 was 0.680.

Table 4. Correlation coefficients (r) from a Pearson correlation matrix between ground and aerial-taken RGB indices and visual wilting score, pod yield, sound mature percent, and crop value evaluated on Aug 3, 10, and 30. Twenty three peanut genotypes were grown under well-watered and water withholding conditions (n = 46) in the field under rainout shelters at the Tidewater AREC in Suffolk, VA, in 2016. RGB indices best correlated with the agronomic characteristics were selected. Parameters a* and u* were defined by the Commision Internationale de l'Eclairage (CIE) in the color spaces CIELAB and CIELUV, respectively (Trussell et al. 2005) and both rate a color on an axis from green to red in terms of sensitivity by the human visual system, and the difference between them is only due to the formula used for calculation. GA is the Green Area index and GGA is the Greener Area index both based on the Hue color space. Data on pictures taken at 3:00 PM on the ground and 9:00 AM from the air are presented here.

	Ground a* Aug 3	Ground u* Aug 3	Ground GA Aug 3	Ground GGA Aug 3	Ground a* Aug 10	Ground u* Aug 10	Ground GA Aug 10	Ground GGA Aug 10	Aerial a* Aug 30	Aerial u* Aug 30	Aerial GA Aug 30	Aerial GGA Aug 30
Visual wilting; Aug 3 @ 15:00	0.738	0.766	-0.588	-0.733	0.824	0.844	-0.688	-0.849	0.817	0.865	-0.687	-0.730
Visual wilting Aug 10 @ 9:00	0.578	0.551	-0.493	-0.509	0.752	0.749	-0.698	-0.739	0.854	0.870	-0.540	-0.615
Visual wilting Aug 10 @ 15:00	0.574	0.544	-0.521	-0.551	0.767	0.747	-0.760	-0.801	0.869	0.878	-0.559	-0.640
Pod yield	-0.535	-0.572	0.489	0.523	-0.608	-0.619	0.412	0.512	-0.643	-0.639	0.380	0.404
Sound Mature Kernels	-0.494	-0.469	0.394	0.328	-0.634	0.636	0.464	0.473	-0.737	-0.697	0.193	0.250
Crop Value	-0.538	-0.576	0.493	0.503	-0.652	-0.671	0.452	0.531	-0.701	-0.686	0.336	0.375