Final + Summary

447/1502 VA 2017

2018 RESEARCH PROPOSAL FINAL REPORT

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

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Principal Investigators:

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Summary

We proposed to validate the use of UAV technology for field selection of drought tolerant peanut varieties. This will help peanut industry as a whole: breeders will have improved tools for selection; farmers will have better yielding varieties; and shellers and processors will have higher quality peanuts from cultivars with improved water use efficiency, which will positively affect maturity and the oleic fatty acid content. During three years of experimentation, we measured plant characteristics associated with water deficit stress on several Virginia- and runner-type genotypes grown in small plots under rain exclusion shelters. Water stress was imposed by covering the plots with the rainout shelters for three weeks from beginning flowering. During this time, the plots were not irrigated nor rained. Wilting was used as the measure of plant stress and was visually assessed. At the same time, wilting was remotely monitored using Red-Green-Blue (RGB), near infrared (NIR), and infrared (IR) plant properties. For these measurements we used handheld devices. After three weeks of water deficit, rain shelters were removed and RGB, NIR, and IR plant properties were assessed with sensors on a drone. We have shown that Green Area (GA) and Greener Area (GGA) derived from the RGB properties, the Normalized Difference Vegetation Index (NDVI) derived from the NIR, and Canopy Temperature (CT) derived from IR were good estimators for wilting, yield, Sound Mature (SMK) kernel content and Crop Value. In addition, both ground and aerial sensing were equally suitable for field selection of drought tolerant varieties, but aerial sensing was faster and more accurate as the information came from the entire plot and not just few plants within each plot.

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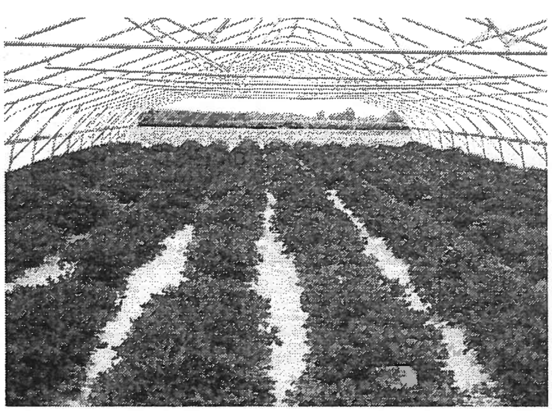
Objectives:

We hypothesized that field evaluation for drought tolerance using UAV technological advances not only saves time and fits better with the weather unpredictability in the VC but also has improved resolution over ground remote sensing. Therefore, our objective were to identify the most reliable RGB, NIR and IR indices taken from an UAV for yield estimation and variety selection for drought tolerance.

We also anticipate 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:

Eighteen peanut varieties were planted each year in a split plot design using two (23 m long by 9 m wide by 3.7 m tall) rain exclusion shelters (Atlas Manufacturing, GA) designated for deficit irrigation. Each shelter accommodated two replications of each variety. Optimally irrigated plots of the same variety were planted outside the rain shelters in two replications. Plot size was 1.8 m long by 0.9 m wide (Fig.1). Irrigation was applied as needed to the optimum irrigated plots by a lateral pull boom cart sprinkler irrigation system (E1025 Reel Rain, Amadas Ind., Suffolk, VA). The cultivars and breeding lines were 'Bailey', 'Sugg', 'Sullivan', 'Wynne', 'Emery', 'Bailey II', 'SPT06-07', 'GA-09B', ' 'TUFRunner297', 'Florida-07', 'N04074FCT', 'N05006', '08X09-1-2-1', '08X09-3-14-1', '09X37-1-19-2', '09X38-1-5-1', '09X38-1-11-2', and '09X44-2-14-1'. At the beginning flowering growth stage (end July), shelters were pooled over the plants and soil water was weekly monitored under each shelter and outside. They were maintained over the plots until the beginning seed stage (end Aug).



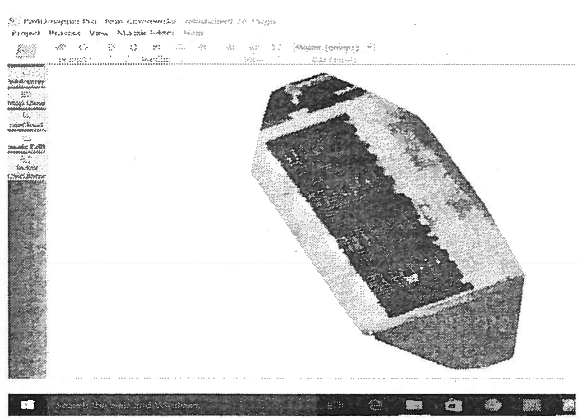


Figure 1. Peanut plots exposed to drought (left) and the orthomosaic (right) after rain shelter removal and aerial imaging in 2017.

Ground evaluations of *leaf colo*r change in response to drought was measured with a Samsung NX300 camera. *Normalized Difference Vegetation Index* (NDVI) was measured with a Trimble GreenSeeker handheld crop reflectance sensor; and *Canopy Temperature (C)* was measured with a handheld AGRI-THERM III IR thermometer (Everest Interscience, AZ). These indices were assessed on weekly basis after drought imposition. Plant height and width, and vine wilting were taken weekly until the vines of two adjacent rows touched.

Aerial evaluations (before and after plots cover with the rain exclusion shelters) included RGB *leaf color* (using Sony Alpha 6000 camera), *NDVI* (using ADC-Lite Tetracam camera), and *CT* (using FLIR camera). Images were taken at 10 to 30 m above the plots and in different waypoint navigation modalities (Hendrik-jan et al., 2004) using an octocopter UAV platform (Ascending Technologies, Germany). Images and in-vegetation collected data were processed with Thermal Editor (Ascending Technologies), Pix4D, ArcGIS, and Image J software (Casadesus and Villegas, 2014).

Yield and grade. Peanuts were dug in early Oct. Pod yield was determined and grading was done in the winter. Ground and aerial indices were compared with yield, grading, and vine wilting to determine what index was best at predicting yield under drought. Varieties were compared for yield under drought and for yield difference between optimal irrigated and drought plots to determine which commercial cultivars were more drought tolerant. Recommendations for farmers were prepared and presented at the spring production meetings.

Results and Discussions:

Current results showed significant differences for yield between the soil water regimes imposed by the rainout shelters and irrigation. In average of all varieties, pod yield decreased by 33% under the rainout shelters compared with irrigated plots. In only 15 days after drought stress imposition, CT became significantly higher (hotter plants) for drought plots (-1.8 °C) than for well-watered plots at noon (-5.2 °C). In the morning, temperature differences between well-watered and drought plots also existed but they were smaller (0.8 versus -0.4 °C). For the NDVI, there were no significant differences between varieties before stress imposition (NDVI was 0.841 in well-watered vs. 0.850 in drought designated plots); but after 6 weeks of differential watering, NDVI was in average 0.892 in drought and 0.917 in well irrigated plots. All color space indices were significantly different between water stressed and well-watered plots starting 20 days after stress imposition; and some were significantly different at only 15 days after shelter covering. For example, on Aug 3, a* was in average -26.88 for drought and -28.92 for well-watered plants. Color space index a* is a measure of the ratio of green to red in an image. More negative numbers indicates greener and less negative less green to reddish plants. For our plots, green was the predominant plot color, but well-watered plots were greener (more negative values for a*). Finally, visual wilting had an average of 1.0 for drought plots and 0.1 for well-watered plots, indicating that drought plants were 10 times more wilted than irrigated plots.

CT, NDVI, and RGB indices estimated reasonably well yield, Sound Mature Kernel (SMK) content, crop value, and plant wilting indicating that they could predict yield and the other agronomic traits with confidence if the 2018 data will confirm this preliminary results (Tables 1-3).

Discoveries:

We delivered a high-resolution peanut variety selection system. The system could be used with marker-assisted selection and genomic selection to expedite development of crops with increased yield and quality. This will ensure agricultural sustainability and profitability, improve the life for growers, and benefit the peanut industry. Food safety and security are major concerns and the proposed project is likely to contribute to superior high-yielding and high-quality peanut crops to benefit society as a whole.

Table 1. **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.**

	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
Probability for genotype effect												
- drought	*0.859*	*0.492*	*0.911*	*0.006*	*0.448*	*0.450*	*0.019*	*0.018*	*0.031*	*0.760*	*0.0001*	*0.0001*
- well-watered	*0.576*	*0.375*	*0.143*	*0.999*	*0.0001*	*0.0001*	*0.001*	*0.408*	*0.041*	*0.0001*	*0.367*	*0.228*

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

Table 2. 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. 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
Probability for the genotype effect													
- drought	*0.930*	*0.010*	*0.215*	*0.055*	*0.0001*	*0.002*	*0.005*	*0.0001*	*0.179*	*0.999*	*0.999*	*0.267*	*0.999*
- well-watered	*0.540*	*0.656*	*0.835*	*0.998*	*0.999*	*0.999*	*0.999*	*0.005*	*0.902*	*0.999*	*0.999*	*0.999*	*0.999*

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

Table 3. **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. 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**

	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
Probability for genotype effect												
- drought	*0.0001*	*0.0001*	*0.147*	*0.003*	*0.0001*	*0.0001*	*0.006*	*0.0001*	*0.048*	*0.013*	*0.038*	*0.0001*
- well-watered	*0.0001*	*0.004*	*0.034*	*0.0001*	*0.997*	*0.998*	*0.678*	*0.554*	*0.005*	*0.002*	*0.236*	*0.063*

Hue color space. Data on pictures taken at 15:00 on the ground and 9:00 from the air are presented here.