Abstract

Project Title: Agronomic Evaluation of Virginia and Runner Type Peanut Cultivars for South Carolina, With Evaluation and Implementation of Improved Monitoring, Production and Harvest Systems – 2016

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Summary:

South Carolina peanut production is unique in straddling the boundary of runner production to the southwest and Virginia-type production to the northeast. Unlike other peanut states where one market type is overwhelmingly predominant, a significant proportion of SC production is in both Virginia-type and runner-type varieties. The end result is that variety evaluation is somewhat more complex than in other southeastern states, and appropriate production systems must be developed for both market types. So although SC is a relatively small state geographically, our peanut growers have big needs when it comes to variety development and performance. This project addresses those needs in both the short and long term in that it evaluates breeder lines for local disease complex tolerance, contributes to belt-wide performance evaluation, and in the short term, gives SC growers the information they need now to make informed variety and market-type contracting choices. Data from this project has provided baseline data of the agronomic and disease performance in South Carolina of newer varieties including TUFRunner 511 and 297, Georgia 14N, TifNV-High O/L, Sullivan, Bailey II and FloRun 157.

In addition, while cover crops have been used in peanut production to varying extents, certain questions for SC growers remain. Data on the effects of extended use of covers to improve SC soil quality and resulting peanut digging conditions, which may potentially lead to less digger losses, is lacking. This point will be addressed and quantified within both the short (1-year) and longer term (4 and 7 years of continued cover crops) portions of this study. The additional organic matter and plant residue in fields with cover crops can have different effects on diseases,
insects, and weeds, and SC growers using covers need to know how their management might need to account for this. From this initial year of data, while there was some evidence that planting peanut by strip tillage into a cover crop could reduce the risk of late leaf spot pressure and assist in managing weeds, there were no clear benefits regarding yield, grade or fungicide management intensity.

Management of peanuts normally uses a blanket approach, applying decisions (e.g., insecticide, irrigation) across an entire field, even though individual problems often begin or occur in highly grouped areas. Site-specific management, such as assisted by the use of an Unmanned Aerial System (UAS), allows problems to be identified and consequently managed on smaller scales, which can save growers time and resources. Though this approach of management has been in the literature for some time, adoption by SC peanut growers has not been widespread. The Federal Aviation Authority is scheduled to finalize rules for allowing the use of UAS for commercial purposes in the near future. Having a platform with demonstrated efficacy in peanut production would allow SC growers to take full advantage of these tools to quickly know the status of their crop and to schedule site-specific management, in turn improving production efficiency. A positive correlation between soil moisture values measured with the NDVI mean calculation from QGIS was observed for each labeled varieties as determined using linear regression analysis. Though the coefficient of determination is not the same for all varieties, an estimate of soil moisture can still be calculated just by the variety and the calculated NDVI from the multispectral sensors attached to a sUAS. Though the results are very promising, additional work needs to be done to validate the soil moisture estimate and the possibility of using one equation for a different variety.

Although several studies have demonstrated technologies suitable for non-destructive peanut moisture sensing, there are no commercially available in-shell moisture sensors for peanut. Development and commercialization of peanut moisture sensors has been slower than for grain crops, likely due to the comparatively smaller market size and due to the added challenges of sensing the kernel moisture content through the hull. Recent studies in peanut yield monitoring have suggested that yield prediction error could be substantially reduced by correction on the basis of moisture content. This study sought to better characterize moisture distribution in peanut and to evaluate a low-cost technology for peanut moisture sensing. Samples of Virginia and runner type peanuts were prepared from 1.5% to 23% whole pod moisture content by adding measured amounts of water to oven dried peanut samples, sealing them in plastic bags, and placing them in a cooler for at least one week to allow the moisture to equilibrate between the kernel and the hull. Conductance of whole pod samples were then measured using an Agritronix hay moisture sensor, and samples were shelled, separated, and oven-dried to independently measure kernel and hull moisture contents. The data suggest an exponential relationship between equilibrium kernel and hull moisture contents ($R^2 = 0.99$), with equilibrium hull moisture contents being an average of 4.0% (w.b.) greater than kernel moisture contents. Conductance was best correlated with hull moisture content; on equilibrated samples, average absolute prediction errors as functions of conductance measurements were 13.0% for hull moisture content, 16.8% for kernel moisture content, and 20.9% for whole pod moisture content.
National Peanut Board Report

Main Body of Report

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Project Component I: Agronomic evaluation of released and advanced lines

Hypothesis and Objectives

By independently evaluating the relative agronomic performance of standard vs. newly released and advanced lines, we can provide useful guidance directly to growers and cooperating breeders. There are three objectives:

1. Provide SC growers with up-to-date information on the best available runner and Virginia-type variety choices and the relative value and returns of contracting for Virginia vs. runner types. This will be accomplished through a variety challenge test focusing on performance of standard vs. newly released lines compared under standard production and digging conditions.

2. Support the Uniform Peanut Performance Trial (UPPT) – a multi-state program comparing performance of advanced breeder lines to selected local standards under standard production conditions.

3. Screen selected experimental and newly released lines vs. resistant standards to quantify tolerance to disease and insect pressure, thereby influencing line advancement and variety management decisions.
Experimental Plan and Methods

Except as specified below, the experimental design and methods will be similar for all objectives in that we will use randomized complete block designs with either 4 (UPPT, disease screen) or 6 reps (variety challenge). Blocks will be formed based on soil conductivity mapping. Traffic/guard rows will be used to prevent plot maintenance traffic adjacent to yield rows after planting. The harvested experimental unit will be 2 rows by 30’ (UPPT, disease screen) or 40’ (variety challenge). Disease evaluations will primarily be made late in the season to best separate performance. Leaf spot will be quantified by visually scanning plots for % symptomatic leaflets and % defoliation. White mold (southern stem rot) will be evaluated immediately after inversion by measuring symptomatic row ft. The same procedure will be used for Cylindrocladium black rot (CBR) and any other soil diseases measurably present. Tomato spotted wilt will be measured as symptomatic row ft before digging. Potato leafhopper injury (% leaflet hopperburn) will be evaluated where measurable. Harvest will be with a Hobbs 2-row combine modified with a load cell basket and dump floor to automate weighing. Grade samples (variety challenge and UPPT) will be drawn from each harvested plot sample to be dried, stored, and graded following USDA standards. Data will be analyzed using generalized linear mixed modeling methods with SAS. All three tests will be performed at Blackville, with a second site for the variety challenge at Florence. Results will be provided directly to growers and industry using annual field days, a statewide annual grower meeting, regional producer meetings for one-on-one communication, regular timely email bulletins, on-farm demonstration and problem site visits, and industry/agent training workshops.

Objective 1: Variety Challenge Test. This test will compare agronomic performance (yield, grade, and any observable pest and environmental response) of newly released vs. standard lines under standard production practices to eliminate disease and insect pest influence. This is essentially a test of “top end” potential crop value (yield plus grade). Separate analysis of Virginia and runner types will be performed. One replicate will be sacrificed prior to maturity to show inverted pods to growers at the annual peanut field day. The remaining five will taken to harvest maturity.

Objective 2: UPPT Test. The uniform peanut performance test is a standardized test conducted annually at nine cooperating sites across the peanut belt from Texas to Virginia. Experimental objectives and methods are essentially like those of objective 1, with the focus here primarily on unreleased lines from a wider geographic area.

Objective 3: Disease Screen. In this test selected advanced and less advanced experimental lines are subjected to a minimal fungicide program (typically three chlorothalonil applications) to evaluate foliar and soil disease susceptibility which would otherwise be confounded by standard protection programs. The objective is to suppress late leaf spot just enough to get useful foliar disease data but still carry the plants to normal harvest maturity for collection of soil disease data after inversion.
Results and Discussion

Variety challenge

Varieties were planted May 12 and grown under irrigation. The top yielding varieties from 2016 were TUFRunner 297, Bailey, Georgia 12Y, Georgia 13M, TUFRunner 511, and TifNV-High O/L (> 5075 lb/A). Of these, Bailey and TUFRunner 297 yielded better at 139 DAP than at 156 DAP. While in 2016 TUFRunner yielded slightly better at 156 than 139 DAP, this increase was marginal and can likely be attributed to excessive evapotranspiration influencing maturity development; this likewise adversely impacted grades in this and other tests at the station. Collectively, relative maturities observed within this irrigated trial are reflective of variety advertised maturity profiles. While Sullivan did not yield as well (~470 lb/A less) as Bailey under this high intensity fungicide management scenario, it had the next most competitive yield among Virginia types, though Wynne yielded approximately 66 lb/A less than Sullivan. FloRun 157 and CHAMPS were in the lowest statistical grouping for yield (< 3750 lb/A). The greatest TSMK grades were associated with TUFRunner 297, Georgia 06G, TUFRunner 511, Georgia 09B, and TifNV-High O/L.

Variety challenge and UPPT maintenance schedule.

<table>
<thead>
<tr>
<th>Date</th>
<th>Product</th>
<th>Rate</th>
<th>Rate unit</th>
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<tr>
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<td>Gypsum</td>
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<td>lb/ac</td>
</tr>
<tr>
<td>May-1-2016</td>
<td>0-0-60</td>
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<td>lb/ac</td>
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<td>Optimize</td>
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<td>10</td>
<td>FL OZ/A</td>
</tr>
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<td>May-14-2016</td>
<td>Prowl H2O</td>
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<td>QT/A</td>
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<tr>
<td>May-14-2016</td>
<td>Valor</td>
<td>3</td>
<td>OZ/A</td>
</tr>
<tr>
<td>May-14-2016</td>
<td>Dual Magnum</td>
<td>1.3</td>
<td>PT/A</td>
</tr>
<tr>
<td>Jun-21-2016</td>
<td>Cadre</td>
<td>4</td>
<td>FL OZ/A</td>
</tr>
<tr>
<td>Jun-21-2016</td>
<td>2,4 DB</td>
<td>1</td>
<td>PT/A</td>
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<tr>
<td>Jun-21-2016</td>
<td>crop oil</td>
<td>1/10</td>
<td>% V/V</td>
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<td>Jun-28-2016</td>
<td>CNI chlorothalonil</td>
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<td>FL OZ/A</td>
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<td>Jul-11-2016</td>
<td>Elatus</td>
<td>9</td>
<td>FL OZ/A</td>
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<td>Jul-27-2016</td>
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<td>FL OZ/A</td>
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<td>Aug-31-2016</td>
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<td>FL OZ/A</td>
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<td>FL OZ/A</td>
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Variety trial yield and grade results, 2016.

<table>
<thead>
<tr>
<th>Runners</th>
<th>Yield (lb/A)</th>
<th>TSMK %</th>
<th>ELK %</th>
<th>OK %</th>
<th>Net loan value ($/ton)</th>
<th>Acre value ($/A)</th>
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<tbody>
<tr>
<td>TUFRunner 297</td>
<td>5583 a</td>
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<td>4.0 bcde</td>
<td>344</td>
<td>962 a</td>
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<tr>
<td>Georgia 12Y</td>
<td>5203 ab</td>
<td>66.8 cdef</td>
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<td>3.9 cde</td>
<td>327</td>
<td>852 ab</td>
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<td>Georgia 13M</td>
<td>5249 ab</td>
<td>65.9 def</td>
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<td>4.3 bcd</td>
<td>323</td>
<td>848 ab</td>
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<tr>
<td>TUFRunner 511</td>
<td>5054 ab</td>
<td>69.3 ab</td>
<td>0.0</td>
<td>3.2 efg</td>
<td>334</td>
<td>846 ab</td>
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<td>TiNV-High O/L</td>
<td>5076 ab</td>
<td>68.8 abc</td>
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<td>2.6 g</td>
<td>330</td>
<td>837 bc</td>
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<td>Florida-07</td>
<td>4966 bc</td>
<td>66.7 cdef</td>
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<td>2.7 fg</td>
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<td>798 bcd</td>
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<td>Georgia 14N</td>
<td>4725 bcd</td>
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<td>767 bcd</td>
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<td>2.6 g</td>
<td>341</td>
<td>717 def</td>
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<td>Georgia 09B</td>
<td>4062 ef</td>
<td>69.3 ab</td>
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<td>4.7 bc</td>
<td>336</td>
<td>685 ef</td>
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<tr>
<td>FloRun 107</td>
<td>4202 def</td>
<td>64.8 f</td>
<td>0.0</td>
<td>3.8 cde</td>
<td>315</td>
<td>665 f</td>
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<tr>
<td>FloRun 157</td>
<td>3495 g</td>
<td>68.0 bcde</td>
<td>0.0</td>
<td>4.8 b</td>
<td>329</td>
<td>575 g</td>
</tr>
</tbody>
</table>

**Virginiyas**

<table>
<thead>
<tr>
<th>Runners</th>
<th>Yield (lb/A)</th>
<th>TSMK %</th>
<th>ELK %</th>
<th>OK %</th>
<th>Net loan value ($/ton)</th>
<th>Acre value ($/A)</th>
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</thead>
<tbody>
<tr>
<td>Bailey</td>
<td>5381 a</td>
<td>66.9 a</td>
<td>41.1</td>
<td>2.6</td>
<td>340</td>
<td>916 a</td>
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<tr>
<td>Sullivan</td>
<td>4911 b</td>
<td>64.2 bc</td>
<td>41.1</td>
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<td>867 b</td>
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<tr>
<td>Wynne</td>
<td>4845 b</td>
<td>62.5 c</td>
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<td>2.7</td>
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<td>775 b</td>
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<tr>
<td>Sugg</td>
<td>4029 c</td>
<td>66.1 ab</td>
<td>42.4</td>
<td>2.3</td>
<td>336</td>
<td>679 c</td>
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<tr>
<td>CHAMPS</td>
<td>3746 c</td>
<td>62.5 c</td>
<td>39.3</td>
<td>2.8</td>
<td>319</td>
<td>569 d</td>
</tr>
</tbody>
</table>

\(^1\)Values within each column and section followed by the same letter are not significantly different (\(\alpha = 0.05\)).

![Physiological leaf spot](image)

111 DAP

Proportion physiological leaf spot.
Most varieties did not develop physiological leaf spot (a.k.a. irregular leaf spot or “funky leaf spot”) to substantial extents. Conversely, TifNV-High O/L developed considerable amounts (~45% leaflet incidence) of physiological leaf spot by 111 DAP; since this condition is not associated with defoliation, its impact on yield or grade is more nebulous. Florida-07 and Georgia 14N developed smaller incidences of physiological leaf spot (< 20%).

Uniform Peanut Performance Test (UPPT)

In the Uniform Peanut Performance Test, TUFRunner 511 was included as one of the local options and served as a relative benchmark for high susceptibility towards tomato spotted wilt virus (TSWV). TSWV pressure in 2016 overall was higher than average. In this test, TUFRunner 511 had ~19% stunting from TSWV. Lines with statistically similar or greater amounts of TSWV stunting compared to TUFRunner 511 were ARSOK-V31, UF 07025, FloRun 157, TxL 080256-02, TxL 080244-03 and TxL 080243-06. The TxL- associated lines had the greatest amounts of TSWV stunting, ranging from 43 to 55%.

Though peanuts were managed with an aggressive fungicide program, elevated amounts of late leaf spot defoliation (>17%) were observed among the released checks of Bailey and Sullivan and the high oleic Bailey backcross derivatives N12008olCLSmT (now known as Bailey II), N12009olCLT, and N12010ol. The statistical grouping with the greatest yields was associated with UF 15303, Wynne, N12008olCLSmT (Bailey II), UF 08036, Bailey, N12009olCLT, N12010ol, TUFRunner 297, UF 07025 and Georgia 13M. Maturity development in this trial was somewhat abnormal considering heat unit accumulation. Unilaterally lower grade certainly supports that no varieties were fully mature at 146 d. Bailey dug at this timing would normally be nearing over maturity. All entries were planted on the same day (May 10), and all entries were dug on October 3.
UPPT line disease and yield performance.

<table>
<thead>
<tr>
<th>Line</th>
<th>TSWV (% stunting)</th>
<th>LLS (% defoliation)</th>
<th>Yield (lb/A)</th>
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</thead>
<tbody>
<tr>
<td>ARSOK-V31</td>
<td>21.7 CD</td>
<td>9.0 C</td>
<td>4305 FG</td>
</tr>
<tr>
<td>AU/NPRL-14-10</td>
<td>10.4 EF</td>
<td>5.0 CDE</td>
<td>4384 EFG</td>
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<td>Bailey</td>
<td>7.1 EFG</td>
<td>32.0 A</td>
<td>5289 AB</td>
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<td>FloRun 157</td>
<td>27.9 C</td>
<td>1.0 EF</td>
<td>4356 EFG</td>
</tr>
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<td>GA 122706</td>
<td>5.0 EFG</td>
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<td>4031 GH</td>
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<td>GA 122707</td>
<td>4.6 FG</td>
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<td>3679 HI</td>
</tr>
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<td>GA 122708</td>
<td>9.6 EF</td>
<td>3.4 DEF</td>
<td>4743 BCDEF</td>
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<td>Georgia 06G</td>
<td>11.7 E</td>
<td>2.1 DEF</td>
<td>4604 CDEFG</td>
</tr>
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<td>Georgia 13M</td>
<td>6.7 EFG</td>
<td>5.8 CD</td>
<td>4965 ABCDE</td>
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<tr>
<td>N12008oICLSmT</td>
<td>4.2 FG</td>
<td>18.4 B</td>
<td>5505 A</td>
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<td>N12009oICLT</td>
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<td>19.2 D</td>
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</tr>
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<td>Txl 080243-06</td>
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<td>Wynne</td>
<td>1.3 G</td>
<td>2.5 DEF</td>
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Values within each column followed by the same letter are not significantly different ($\alpha = 0.05$).

UPPT line grade performance.

<table>
<thead>
<tr>
<th>Line</th>
<th>Fancy Pods (%)</th>
<th>TSMK (%)</th>
<th>OK (%)</th>
<th>Meats (%)</th>
<th>ELK (%)</th>
<th>Med. (%)</th>
<th>No. 1 (%)</th>
<th>SMK (g/100)</th>
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<tr>
<td>Bailey</td>
<td>84.4</td>
<td>61.8</td>
<td>1.9</td>
<td>63.7</td>
<td>38.9</td>
<td>11.7</td>
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<td>Georgia 06G</td>
<td>67.0</td>
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Disease screen

Disease screen maintenance schedule.

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<tr>
<th>Date</th>
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<th>Rate unit</th>
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<tr>
<td>Apr-18-2016</td>
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<td>lb/ac</td>
</tr>
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<td>Optimize</td>
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<td>FL OZ/A</td>
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<td>FL OZ/A</td>
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<td>1</td>
<td>QT/A</td>
</tr>
<tr>
<td>May-14-2016</td>
<td>Valor</td>
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<td>% V/V</td>
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<td>Jun-27-2016</td>
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<td>Bravo WS</td>
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<td>pt/ac</td>
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Peanuts were planted May 12 and grown under irrigation. Late leaf spot pressure started to build relatively late in 2016 compared to most years. The statistical grouping with the greatest late leaf spot defoliation included N12015ol, N12014ol and FloRun 157 (> 56% defoliation). The grouping with the next highest late leaf spot defoliation included FloRun 157, 09X38-1-5-1, N10046ol, N13003olF and 09X39-1-11-2 (defoliation between 43 and 56%). N14035olSmT was the unreleased line with the lowest late leaf spot defoliation (12.5%, similar to Sullivan’s 12.8%), which was followed by N13054ol. The Carolina African Runner by far had the most TSWV stunting, at approximately 96% in this test and 68% in a different test and field. The statistical grouping with the second highest amount of TSWV stunting included CHAMPS, TUFRunner 727, N11020olJ, FloRun 157 and TUFRunner 511 (grouping ranging from 38 to 52% stunting). Despite this field having a history of white mold (stem rot) disease pressure, white mold levels failed to develop to substantial levels.
2016 disease screen results from Blackville, South Carolina.†

<table>
<thead>
<tr>
<th>Line</th>
<th>TSWV stunt</th>
<th>LLS defoliation</th>
<th>WM severity</th>
<th>Yield (lb/A)</th>
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<tr>
<td>08X09-3-14-1</td>
<td>0.29 E-I</td>
<td>0.22 E-L</td>
<td>0.02 D-F</td>
<td>3220 A-E</td>
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<tr>
<td>09X38-1-5-1</td>
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<td>0.52 B</td>
<td>0.03 C-F</td>
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<tr>
<td>09X39-1-11-2</td>
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<td>0.43 B-D</td>
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<td>Georgia 06G</td>
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<td>0.1 LM</td>
<td>0.07 A-C</td>
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†Admire Pro used in-furrow; fungicide input was three Bravo applications. Values within each column followed by the same letter are not significantly different (α = 0.05).
Project Component II: Evaluation of short and extended cover crop use on South Carolina peanut production

Hypothesis and Objectives

This study is designed to address the hypothesis that pest suppression in cover crops will allow for a decrease in the amounts of pests (e.g., diseases, weeds) in the following peanut crop and reduced input costs associated with effective management. The corresponding objective will be to quantify the reduction of diseases/weeds associated with cover crop use in SC peanut production and estimated management cost (time + monetary). It is also hypothesized that cover crops will improve the quality of the soil (e.g., improved water holding capacity) and that this will subsequently enhance yield and grade compared with SC peanuts grown with no cover crop. Objectives relevant to this hypothesis will be to measure yield and grade of peanuts from different treatments and to estimate differences in related digging time and/or force to determine the extent to which cover crops affect yield, grade and harvest practices during both the short (1-year) and longer term (4- and 7-year) portions of this study.

Experimental Plan and Methods

Treatments will be applied according to a split-split plot experimental design and will be replicated 5 times. Cover crop (rye, rye + crimson clover, or none) will be assigned to main plot, peanut variety (‘Bailey’ and ‘Georgia 06G’, the most common Virginia and runner varieties grown in SC) will be assigned to sub plot, and fungicide management intensity (high, medium, low, and no herbicide/fungicide treatment) will be assigned to sub-sub plot. High management intensity treatments will include premium fungicides (e.g., Convoy + Bravo, Provost) on a 5-spray program. Medium management intensity treatments will include one Bravo spray followed by 4 Bravo + tebuconazole sprays. Low management intensity treatments will only have 3 Bravo sprays. The no herbicide/fungicide treatment will not be chemically managed for weeds or disease. Insecticides will be applied on an as-needed basis, with insect damage and number of insecticide applications being recorded appropriately. To obtain results relevant to irrigating and non-irrigating growers alike, this experiment will be conducted on both an irrigated field and a non-irrigated field. During the first year of the study, cover crops will be planted in the fall into disced cotton stubble. Termination of cover crops in the following spring will be scheduled based on a combination of time before planting peanuts (e.g., 21 days) and soil moisture conditions. Peanuts will be planted into strip-tilled herbicide-terminated cover crops. Blocks will be constructed and disease evaluations conducted as described under Project Component I. After conclusion of the 2016 peanut crop season, cover crops will be planted in the same field locations between cash crop seasons, and peanuts will be rotated with corn and cotton. This rotation will continue with peanuts again being planted in 2019 and 2022. This will allow results to be representative of crop rotation practices and will provide information on a longer term basis that is applicable to SC peanut growers. Conducting this study in a crop rotation setting is beneficial as well as necessary, since if peanuts were continually cropped, results would become skewed and misleading due to dramatically increased disease severity. The study will be performed at the Edisto Research and Education Center research farm in Blackville, SC. Data will be analyzed using generalized linear (and nonlinear, where appropriate) mixed modeling methods with SAS.
Cover crop test maintenance schedule – irrigated field.

<table>
<thead>
<tr>
<th>Date</th>
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<th>Rate</th>
<th>Rate unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-15-2016</td>
<td>S-25 nitrogen</td>
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<td>A/A</td>
</tr>
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<td>Round Up</td>
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</tr>
<tr>
<td>Apr-24-2016</td>
<td>2,4 D</td>
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</tr>
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</tr>
<tr>
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<td>Prowl H20</td>
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<td>May-27-2016</td>
<td>Valor</td>
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<tr>
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</tr>
<tr>
<td>Jun-29-2016</td>
<td>2,4 DB</td>
<td>1 pt/ac</td>
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<tr>
<td>Jun-29-2016</td>
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<td>Crop Oil</td>
<td>1 % V/V</td>
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</tr>
</tbody>
</table>

Cover crop test maintenance schedule – dryland field.

<table>
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<th>Date</th>
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<th>Rate</th>
<th>Rate unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-15-2016</td>
<td>S-25 nitrogen</td>
<td>30 LB</td>
<td>A/A</td>
</tr>
<tr>
<td>Apr-18-2016</td>
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<td>AC</td>
</tr>
<tr>
<td>Apr-18-2016</td>
<td>0-0-60</td>
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</tr>
<tr>
<td>Apr-24-2016</td>
<td>Round Up</td>
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<td>A</td>
</tr>
<tr>
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Results and Discussion

Covers were planted December 4, 2015 by drill with peanuts being planted May 26 (dryland) and May 27 (irrigated). The crimson clover seed in the rye + clover cover treatment failed to produce an adequate clover stand, and as such this blend was practically another rye treatment for the purpose of the 2016 data.

When the no herbicide check treatment was removed from the analysis of the irrigated field data, cover crop did not have a significant effect on yield alone or when interacting with management intensity, cultivar, or both management intensity and cultivar ($P > 0.076$). Grade (TSMK) was not improved in cover treatments compared to conventional no cover production in either of the two fields. While these tests were managed without soil fungicides, white mold (stem rot) severity was less than 2% for all treatments in both the irrigated and dryland fields. Late leaf spot defoliation was not significantly influenced in the irrigated field ($P > 0.086$), though there was a slight trend for less late leaf spot defoliation in the cover treatments compared to the conventional no cover system. This difference here was not enough to influence spray schedule or yield, but it did help somewhat to reduce overall levels of late leaf spot risk, which corroborates risk associated with tillage method as per Peanut Rx.

The predominately weed populations in the irrigated test were Palmer amaranth, yellow nutsedge, and annual grasses (mix of crabgrass and goosegrass). No differences were observed between the rye+ clover and rye alone in weed populations. Overall, the presence of a cover crop species provided good to excellent suppression of the weed populations (as observed in the NoH treatments for both varieties). In contrast, the no cover treatment contained a higher incidence of weeds, even in the low, med, and high management treatments where a herbicide program was used. The combination of a cover crop with the appropriate herbicide management system controlled the populations of Palmer amaranth, yellow nutsedge, and the annual grasses.

In the dryland field late leaf spot pressure was lower than the irrigated field. No significant differences were seen among fungicide management defoliation levels across the cover treatments for Georgia 06G. In the dryland field, no significant differences were seen in Sullivan across cover treatments for the 5 Bravo spray program. For the 4 Bravo spray program, significantly more defoliation (18%) was in the Sullivan rye treatment compared to conventional (4%) and “blend” (5%) Sullivan, which again ended up as essentially another rye treatment due to lack of clover growth. Also for Sullivan, under the 3 Bravo spray program, there was significantly less defoliation in blend treatment (38%) compared to the conventional treatment (65%), though defoliation in the rye treatment (68%) at this management level was essentially the same as the conventional. The baseline data from these tests did not result in a measureable improvement to yield or grade for Georgia 06G or Sullivan, or for late leaf spot management under the 4 or 5 Bravo spray programs. This was following one season of cover crop use and as such did not evaluate potentially accumulated effects of soil modification over multiple years.

The results for the dryland test were similar to the irrigate test, weed populations observed were Palmer amaranth, yellow nutsedge, and annual grasses (mix of crabgrass and goosegrass). The presence of a cover crop species terminated biomass provided good to excellent suppression of
the weed populations (as observed in the NoH treatments for both). In contrast, the no cover treatment contained a higher incidence of weeds, even in the low, med, and high management treatments where a herbicide program was used. The combination of a cover crop with the appropriate herbicide management system effectively managed populations of Palmer amaranth, yellow nutsedge, and the annual grasses in the dryland environment.

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<th>Yellow Nutsedge</th>
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LSD (0.05) 0.6 0.9 0.8

Management levels included high: 5 Bravo sprays, med: 4 Bravo sprays, low: 3 Bravo sprays, NoH: no fungicide or herbicide management. Grade and value was only determined for treatments with medium or high fungicide management.
Dryland cover crop average weed species populations counted at the end of season (August).

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<th>Palmer Amaranth plants m⁻²</th>
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LSD (0.05) 1.7 2.4 4.6

Management levels included high: 5 Bravo sprays, med: 4 Bravo sprays, low: 3 Bravo sprays, NoH: no fungicide or herbicide management. Grade and value was only determined for treatments with medium or high fungicide management.
Irrigated cover crop test yield, grade and value.

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Management levels included high: 5 Bravo sprays, med: 4 Bravo sprays, low: 3 Bravo sprays, NoH: no fungicide or herbicide management. Grade and value was only determined for treatments with medium or high fungicide management. Values within each column followed by the same letter are not significantly different (α = 0.05).
Dryland cover crop test yield, grade and value.

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<th>Variety</th>
<th>Fungicide management</th>
<th>Acre value ($/A)</th>
<th>Yield lb/A</th>
<th>% TSMK</th>
<th>% ELK</th>
<th>$/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye + clover</td>
<td>Georgia 06G</td>
<td>Low</td>
<td>3870 BCD</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med</td>
<td>4385 ABC</td>
<td>70.2</td>
<td>...</td>
<td>...</td>
<td>342</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4301 ABC</td>
<td>70.5</td>
<td>...</td>
<td>...</td>
<td>344</td>
</tr>
<tr>
<td>No cover</td>
<td></td>
<td>Low</td>
<td>4136 ABCD</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>4475 ABC</td>
<td>71.5</td>
<td>...</td>
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<td>346</td>
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<tr>
<td></td>
<td></td>
<td>High</td>
<td>4540 ABC</td>
<td>72.1</td>
<td>...</td>
<td>...</td>
<td>348</td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td>Low</td>
<td>3986 BCD</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med</td>
<td>4284 ABC</td>
<td>70.8</td>
<td>...</td>
<td>...</td>
<td>342</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4813 A</td>
<td>72.1</td>
<td>...</td>
<td>...</td>
<td>349</td>
</tr>
<tr>
<td>Rye + clover</td>
<td>Sullivan</td>
<td>Low</td>
<td>3447 D</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med</td>
<td>4248 ABC</td>
<td>57.3</td>
<td>30.2</td>
<td>297</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4079 ABCD</td>
<td>59</td>
<td>31.9</td>
<td>304</td>
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</tr>
<tr>
<td>No cover</td>
<td></td>
<td>Low</td>
<td>3463 D</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med</td>
<td>4616 AB</td>
<td>58.9</td>
<td>32.3</td>
<td>305</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4799 A</td>
<td>59.1</td>
<td>32.9</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td>Low</td>
<td>3821 CD</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med</td>
<td>4434 ABC</td>
<td>59</td>
<td>32.7</td>
<td>305</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>4160 ABC</td>
<td>58</td>
<td>33.1</td>
<td>300</td>
<td></td>
</tr>
</tbody>
</table>

Management levels included high: 5 Bravo sprays, med: 4 Bravo sprays, low: 3 Bravo sprays, NoH: no fungicide or herbicide management. Grade and value was only determined for treatments with medium or high fungicide management. Values within each column followed by the same letter are not significantly different (α = 0.05).
Irrigated cover crop disease ratings.

<table>
<thead>
<tr>
<th>Cover</th>
<th>Management</th>
<th>Variety</th>
<th>LLS % defoliation</th>
<th>WM % severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye + clover</td>
<td>High</td>
<td>Georgia 06G</td>
<td>34 GH</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>25.4 H</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>87.4 AB</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>54 EF</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>55 EF</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>99.8 A</td>
<td>0 B</td>
</tr>
<tr>
<td>None</td>
<td>High</td>
<td>Georgia 06G</td>
<td>50 EFG</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>37.6 FGH</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>85 ABC</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>64.4 DE</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>66.4 CDE</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>98.6 AB</td>
<td>0.25 A</td>
</tr>
<tr>
<td>Rye</td>
<td>High</td>
<td>Georgia 06G</td>
<td>32.5 GH</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>38 FGH</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>80 BCD</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>83.6 ABC</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>53 EF</td>
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<tr>
<td></td>
<td>Low</td>
<td></td>
<td>99.4 A</td>
<td>0 B</td>
</tr>
</tbody>
</table>

Values within each column followed by the same letter are not significantly different (α = 0.05).

Dryland cover crop disease ratings.

<table>
<thead>
<tr>
<th>Cover</th>
<th>Management</th>
<th>Variety</th>
<th>LLS % defoliation</th>
<th>WM % severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye + clover</td>
<td>High</td>
<td>Georgia 06G</td>
<td>2.6 E</td>
<td>0.67 AB</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>3 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>7.6 CDE</td>
<td>0.67 AB</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>1.8 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>4.8 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>38 B</td>
<td>0 B</td>
</tr>
<tr>
<td>None</td>
<td>High</td>
<td>Georgia 06G</td>
<td>3.5 E</td>
<td>0.83 AB</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>4.25 E</td>
<td>0.83 AB</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>19.25 C</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>5.25 DE</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>3.5 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>65.25 A</td>
<td>0.28 AB</td>
</tr>
<tr>
<td>Rye</td>
<td>High</td>
<td>Georgia 06G</td>
<td>2.6 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>3.6 E</td>
<td>1.11 A</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>11.2 CDE</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Sullivan</td>
<td>2.2 E</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td></td>
<td>17.6 CD</td>
<td>0 B</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td>67.6 A</td>
<td>0.44 AB</td>
</tr>
</tbody>
</table>

Values within each column followed by the same letter are not significantly different (α = 0.05).
**Project Component III:** Remote sensing with an unmanned aerial systems to monitor and assess peanut production in South Carolina

**Hypothesis Objectives**

The hypothesis for this work is that different stresses lower photosynthetic activity of peanut leaves and that different sources of stress (e.g., water stress vs. insect damage) can be differentiated and quantified based on these amounts. The specific objectives of this study are to:

- Quantify photosynthetic activity of peanut concerning stress source by measuring the infrared reflectance of the plant;
- Study the effect of UAS altitude (10, 20, and 30 meters) in data collection of infrared reflectance;
- Explore the effect of two filter types for the near-infrared sensors (Linear polarizers and Ultra Violet (UV)) on measuring the stress of peanut.

**Materials and Methods**

**Locations.** Research was performed on three different areas in Edisto Research & Education Center in Blackville, South Carolina. They are as follows:

- Plot 1: 33°20'39.9"N 81°18'02.7"W, with an elevation of 88m
- Plot 2: 33°21'26.5"N 81°18'24.9"W, with an elevation of 96m
- Plot 3: 33°21'34.7"N 81°19'54.8"W, with an elevation of 101m

Each of the plot locations consisted of five different varieties of peanuts.

Since this is a preliminary study on peanuts and their correlation of water content and Normalized Difference Vegetation Index (NDVI), there were no validation sites for a prediction model. The prediction model will be developed if this work will be funded for an additional year.

**Small Unmanned Aerial Vehicle.** The sUAV used in this work is an Inspire 2 (Da Jiang Innovations, Shenzhen, China). The sUAV is a multi-rotor type with four retractable propellers, and the frame consists of a magnesium aluminum composite shell with a carbon fiber arm. (See Fig. 1a). It has a dual self-heating battery to provide redundancy. This type of sUAV is specifically designed for filmmaking. The camera used for normal imagery is the X4S Camera from the same manufacturer.

**Multi-spectral sensors.** There were three different multispectral sensors used for this project: modified Canon Camera Elph130IS (Canon, One Canon Park, NY, USA), MAPIR Survey2 (Peau Productions, San Diego, CA, USA), and Parrot Sequoia (Micasense Inc., Seattle, WA, USA). A carbon-fiber mount was created for these three different multispectral sensors to hold all the sensors, including the battery, for the Parrot Sequoia (See Fig. 1b).
sUAS Flights and Image Acquisition. A set of remote images of the three plots were acquired on July 27, 2017, August 23, 2017, and September 29, 2017. During each flight, the sUAS route was created through an Apple Ipad Pro app (DJI GS Pro) (Fig. 2a) with 50 waypoints. Though there were three proposed altitudes for this proposal, the altitude that was ultimately used for the three plots was 120 m. This was due to the size of each plot and the battery capacity of the sUAS and load (sensors). A forward and side lap of 80% and 70% respectively was set to collect each trigger from the sensors.

Image Analysis. The set of sUAS aerial images were processed to create an ortho-mosaic image of each of the multispectral sensors using Agisfot Photoscan Professional Software (Agisoft LLC, St. Petersburg, Russia). This automatic process involved aligning images, building a dense cloud, mesh, and generating an ortho photo. The resulting images were then calibrated using the different calibration panel provided by the manufacturer (Fig. 2b).

The ortho-photo generated from the multispectral sensors were geo-referenced using QGIS Software (QGIS Geographic Information System, Open Source Geospatial Foundation, http://qgis.osgeo.org). The same software was used to generate the calculated NDVI data layer using the Raster Calculator. Each of the plot (See Fig. 3) was then segmented using a SpatiaLite
layer of QGIS where the mean, median of the NDVI of one segment area (indicated on a purple area in Fig. 3) can be calculated.

![Image](image.png)

**Figure 3.** QGIS Software used to georeference sensor data and calculate NDVI layer.

**Results and Discussion**
The soil moisture data from Plot 2 (33°21’26.5"N 81°18’24.9"W, with an elevation of 96m) are shown in Fig. 4. These data were from labels 201–208 (as shown in Fig. 3). These time-series data were collected between 10:00 AM – 12:00 AM on July 27, 2017, August 23, 2017, and September 29, 2017, as the sUAS flew during this time interval.

![Graphs](graphs.png)

**Figure 4.** Time series data of the Soil Moisture of Plot 2 label: 201–208

The average soil moisture was then calculated to represent a soil moisture value for each of the peanut types (TuffRunner 511, Ga 12Y, Ga 06G, and Ga 13M). The soil moisture was then
compared to the calculated NDVI from QGIS. Below are the two tables for the average soil moisture (Table 1) and the NDVI mean (Table 2) for each labeled peanuts varieties.

**Table 1. Average Soil Moisture for each labelled peanuts varieties. (201 & 205 = TuffRunner, 202 & 206 = Ga 12Y, 203 & 207 = Ga 06G, and 204 & 208 = Ga 13M)**

<table>
<thead>
<tr>
<th>Flight Dates</th>
<th>201</th>
<th>202</th>
<th>203</th>
<th>204</th>
<th>205</th>
<th>206</th>
<th>207</th>
<th>208</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 27, 2017</td>
<td>0.103</td>
<td>0.116</td>
<td>0.097</td>
<td>0.107</td>
<td>0.093</td>
<td>0.097</td>
<td>0.084</td>
<td>0.101</td>
</tr>
<tr>
<td>Aug. 23, 2017</td>
<td>0.035</td>
<td>0.028</td>
<td>0.017</td>
<td>0.018</td>
<td>0.011</td>
<td>0.022</td>
<td>0.018</td>
<td>0.036</td>
</tr>
<tr>
<td>Sept. 29, 2017</td>
<td>0.058</td>
<td>0.053</td>
<td>0.033</td>
<td>0.029</td>
<td>0.022</td>
<td>0.050</td>
<td>0.031</td>
<td>0.046</td>
</tr>
</tbody>
</table>

**Table 2. NDVI mean calculated using QGIS for each labeled peanuts varieties. (The same label numbers and varieties as in Table 1.0)**

<table>
<thead>
<tr>
<th>Flight Dates</th>
<th>201</th>
<th>202</th>
<th>203</th>
<th>204</th>
<th>205</th>
<th>206</th>
<th>207</th>
<th>208</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 27, 2017</td>
<td>0.431</td>
<td>0.488</td>
<td>0.392</td>
<td>0.453</td>
<td>0.515</td>
<td>0.465</td>
<td>0.363</td>
<td>0.425</td>
</tr>
<tr>
<td>Aug. 23, 2017</td>
<td>0.386</td>
<td>0.366</td>
<td>0.405</td>
<td>0.341</td>
<td>0.221</td>
<td>0.364</td>
<td>0.418</td>
<td>0.391</td>
</tr>
<tr>
<td>Sept. 29, 2017</td>
<td>0.395</td>
<td>0.411</td>
<td>0.354</td>
<td>0.361</td>
<td>0.377</td>
<td>0.394</td>
<td>0.351</td>
<td>0.400</td>
</tr>
</tbody>
</table>
A positive correlation between soil moisture values measured with the NDVI mean calculation from QGIS was observed for each labeled variety as determined using linear regression analysis. The coefficients of determination ranged from 0.624 to 0.9916 across varieties as shown in Figure 5.

![Graphs showing correlations between soil moisture values and calculated NDVI from multispectral sensors.](image)

**Figure 5. Correlations between soil moisture values and calculated NDVI from multispectral sensors.**

These correlations as shown in Figure 5 showed a promising result that can be used to predict soil moisture for each of the varieties using only the calculated NDVI from the multispectral sensors attached to a sUAS. The soil moisture could be estimated from the following equation below:

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Soil Moisture Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuff Runner 511</td>
<td>$0.5832n^2 - 0.102n + 0.0011$</td>
</tr>
<tr>
<td>Ga 12Y</td>
<td>$0.7287n - 0.2412$</td>
</tr>
<tr>
<td>Ga 06G</td>
<td>$0.9675n - 0.3214$</td>
</tr>
<tr>
<td>Ga 13M</td>
<td>$0.871n - 0.2882$</td>
</tr>
</tbody>
</table>

**Table 3. Estimated Soil Moisture Equation using NDVI values.** $n$ is the calculated NDVI.

**Validation.** The result on Fig. 5 showed that there is a strong correlation between the soil moisture data and the calculated NDVI from the multispectral sensors, but these results only provide training data sets. There is a need to validate this result with the same setup of peanut varieties each with soil moisture sensors. The validation will provide twofold: enhance the soil moisture estimate equation in Table 3 and provide a unified equation that can be used across varieties.
Conclusions
A positive correlation between soil moisture values measured with the NDVI mean calculation from QGIS was observed for each labeled varieties as determined using linear regression analysis. Though the coefficient of determination is not the same for all varieties, an estimate of soil moisture can still be calculated just by the variety and the calculated NDVI from the multispectral sensors attached to a sUAS. Though the results are very promising, additional work needs to be done to validate the soil moisture estimate and the possibility of using one equation for a different variety.

Project Component IV: Validation and continued development of a peanut yield monitor

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Orlando, Florida
July 17-20, 2016

Introduction
Several studies have evaluated and developed technologies for non-destructive, in-shell measurement of moisture in peanut (Kandala and Butts, 2008; Trabelsi et al., 2009; Lewis et al., 2013; Kandala and Sundaram, 2014; Lewis et al., 2016) but no technologies are commercially available for hand-held or on-combine application. The contributing factors in delay of commercial offering of an in-shell peanut moisture sensor are in part due to the relatively small market size, e.g., when compared to corn and small grains. Several manufacturers offer commercially available handheld and benchtop products available for kernel moisture content of shelled, static peanut samples, for example: AgraTronix, DICKEY-john, Farmex, Seedburo, Shore Measuring Systems, and Steinlite. In-shell measurements would be valuable to growers and buy points because such technologies would eliminate the need for shelling the pods prior to making the measurements. Conventional harvesting of peanut involves digging the vines with a digger/shaker/inverter at optimal pod maturity and leaving the inverted vines in the field for some period of time to dry prior to threshing the pods off of the vines with a peanut combine. Ability to make rapid in-field measurements of peanut moisture content would aid growers in making decisions about when and where to combine peanuts. Currently, growers must either gather a sample to be shelled and carried to a buying point for evaluation, or often times they may harvest one full truckload or wagonload, using the results from moisture samples at the buy point to evaluate whether or not to continue harvest in that field.

In-shell peanut moisture content is inherently challenging to measure because there are three distinct moisture contents that may be measured: hull, kernel, and whole pod. Kernel moisture content is of important value to growers and merchandisers because it is used to define suitability
for storage (USDA-AMS, 2017) and therefore the basis for drying costs imposed on the producer. Whole pod moisture content is valuable from the producer’s standpoint because if used in combination with field weight knowledge, it provides the best projection of sale weight after drying. Whole pod moisture content would particularly be useful for application to peanut mass flow data to convert wet yields to dry yields, which represent a better measure of revenue. While knowledge of the hull moisture content may not be of direct or obvious value, it may be the easiest moisture content to sense for in-shell samples because the hull can be in closest proximity to the sensing elements, especially when considering capacitance and conductance technologies. Although the hull moisture content in itself is not of obvious value, knowledge of relationships between hull and kernel moisture contents may allow for estimation of kernel moisture content as a function of estimated hull moisture content.

Studies have indicated potential value in knowledge of moisture content with respect to peanut yield monitoring. In corn and grain yield monitoring, it is common today to include a moisture sensor, which is used to convert wet mass flow rates and yields to dry mass flow rates and yields. On these systems, wet mass flow prediction is computed independently from sensed moisture contents. As suggested in Fravel et al. (2013), Porter et al. (2013), and Thomasson et al. (2016) peanut moisture content may additionally be useful in wet mass flow rate prediction; i.e., it would be used as an additional independent variable for predicting wet mass flow rates, in addition to its use in converting wet to dry mass flow rates. It has been suggested that some knowledge of moisture content, even if not as accurate as alternative methods, would be useful in correcting wet mass flow predictions. Importance in this application is more evident when considering that peanut moisture variability within a field can be quite large due to differences in pod maturity as a function of in-season growing conditions and differences in windrow drying rates as functions of vine mass, shading, and adhered soil; many of these factors are affected by local soil types, which can vary widely in the southeastern coastal plains where many U.S. peanuts are grown.

The objectives of this project were to: (1) characterize relationships between hull, kernel, and whole pod moisture contents on equilibrated in-shell peanut samples and (2) evaluate accuracy of using a conductance measurement for in-shell prediction of hull, kernel, and whole pod peanut moisture contents.

Procedures

Bulk samples of Virginia and runner type peanut were collected from combines and dried to less than 5% moisture content; the bulk samples were composites from mixed varieties and multiple fields for each type. From these bulk samples, 300 g subsamples were collected, to which moisture was reconstituted for establishment of whole pod moisture contents ranging from about 3% to 27%, w.b. The subsamples were placed in sealable plastic bags and weighed as the reconstituted moisture was applied by spraying mists of water into the bag. Each bag was sealed and shaken to distribute the reconstituted water, then placed in a cooler at 38 °C for one week to prevent spoilage while the moisture equilibrated between the hulls and the kernels. Samples removed from the cooler were assigned one of five treatments: equilibrated (n=87), 1 hr hull-dry (n=32), 10 min hull-dry (n=46), 2 g hull-wet (n=47), and 4 g hull-wet. All samples were set out
of the cooler, remaining sealed at room temperature for at least two hours prior to testing to reduce likelihood of condensation on the pod surfaces when the bags were opened for testing.

Conductance measurement, shelling, separating, and drying was carried out using the same methods for all three treatments, as explained below. Prior to conductance measurement, samples for the 1 hr hull-dry and 10 min hull-dry treatments were dried for 1 hr and 10 min, respectively, in a Blue M forced air drying oven at 50 °C to decrease the hull to kernel moisture content ratios with respect to those at equilibrium. Prior to conductance measurement, samples for the 2 g hull-wet and 4 g hull-wet treatments were misted with an additional 2 g and 4 g of water to increase the hull to kernel moisture content ratios with respect to those at equilibrium. Samples for the 2 g hull-wet and 4 g hull-wet treatments were resealed and shaken immediately after misting, and allowed to sit for 10 min and 20 min, respectively, prior to measuring conductance to allow the surface moisture to be absorbed by the hulls. The assigned times of 10 min and 20 min were selected to allow sufficient time for moisture absorption into the hull, but not so much time that the kernel moisture content would be substantially affected.

Conductance measurement was conducted using an AgraTronix BHT-2 (Streetsboro, Ohio) hay moisture sensor pad mounted in the bottom of a plastic container (fig. 1a). Peanut depth above the sensor pad was generally about 3 in. One electrode of the BHT-2 moisture pad was connected to a 5 V supply from a Phidgets model 1018 interface kit and the other electrode was connected to a Phidgets model 1134 voltage divider with the contact between ground and the 1 MΩ resistor closed and all other contacts to ground open as seen in figure 1b. The output indicated in figure 1 was delivered to one of the analog inputs on the interface kit and logged at 100 Hz using custom software written in Microsoft Visual Basic language. Logging began within 10 s of placing the pods in the chamber and continued for a duration of 10 s for each sample. Voltage return for each test was recorded as the average of sensed voltages during the 10 s logging period. Sensed voltages were converted to resistance values by calibrating the voltage divider circuit to known resistances placed across the hay moisture pad electrodes (fig. 2). Reciprocals of the resistance values were calculated to obtain conductance values for each reading.
Figure 1. Mounting configuration of AgraTronix hay moisture pad in test container (a) and electrical connection of the AgraTronix hay moisture pad, “Hay MS”, with respect to the voltage divider. The output was delivered to one of the analog inputs of the interface kit.

Figure 2. Calibration of measured resistance across hay moisture pad electrodes as a function of the reciprocal of the analog response.

Immediately after logging data for each sample using the hay moisture sensor, the samples were shelled using a custom built peanut sheller (fig. 3a), which was similar in construction to the Pearman peanut sheller (fig. 3b). Each shelled sample was then separated into hulls and kernels using a seed cleaner (Hege Equipment Inc., Colwich, Kans.). Hulls and kernels were then independently weighed to a resolution of 0.01 g to obtain wet weights and placed in an oven at 70 °C for one week, which was determined to be a sufficient length of time for sample weight to stabilize. After one week in the oven, samples were once again weighed to a resolution of 0.01 g to obtain dry weights. In addition to the five treatments indicated above, 42 runner type samples collected from the cross-auger or inlet duct of a peanut combine were also tested in the same manner: measuring conductance, shelling, separating, and drying. There were an additional 75 runner type samples collected from the inlet duct of a peanut combine, which were shelled,
separated, and dried, but conductance was not measured. All combine samples were immediately placed in sealed plastic bags when collected and tested within 2 hours of sampling.

(a)

(b)

Figure 3. Custom built peanut sheller (a) used in this study and Pearman peanut sheller (b), both of which are similar in construction.

Results and Discussion

Results from the equilibrated treatment were used to characterize relationships between hull, whole pod, and kernel moisture contents, all of which demonstrated strong correlations ($R^2 \geq 0.985$), and none of which were substantially different for runner or virginia type peanuts. Figure 4 demonstrates some of these relationships for the combined datasets of runner and virginia type peanut. Regression equations relating hull, kernel, and whole pod moisture contents for runner and virginia type combined, runner type, and virginia type peanut are provided in table 1. This study did not assess equilibrium moisture content relationships for hull moisture contents in excess of 28% w.b., kernel moisture contents in excess of 22% w.b., or whole pod moisture contents in excess of 24% w.b.; figure 4a suggests that the trend in kernel moisture content may begin to plateau or otherwise diverge from a power function with respect to hull moisture content at hull moisture contents of about 26% w.b., although further study would need to be conducted to confirm.
Table 1. Moisture relationships for runner and virginia type peanut at equilibrium moisture conditions.\[^{[a]}\]

<table>
<thead>
<tr>
<th>Runner and Virginia Type (n=87)</th>
<th>(R^2)</th>
<th>Runner Type (n=43)</th>
<th>(R^2)</th>
<th>Virginia Type (n=44)</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(MC_K = 0.2015 \cdot MC_H^{1.4567})</td>
<td>0.989</td>
<td>(MC_K = 0.1656 \cdot MC_H^{1.525})</td>
<td>0.985</td>
<td>(MC_K = 0.2111 \cdot MC_H^{1.4406})</td>
<td>0.991</td>
</tr>
<tr>
<td>(MC_H = 3.0568 \cdot MC_K^{0.679})</td>
<td>0.989</td>
<td>(MC_H = 3.3295 \cdot MC_K^{0.6461})</td>
<td>0.985</td>
<td>(MC_H = 2.9869 \cdot MC_K^{0.6876})</td>
<td>0.991</td>
</tr>
<tr>
<td>(MC_K = 0.5464 \cdot MC_P^{1.1855})</td>
<td>0.998</td>
<td>(MC_K = 0.5699 \cdot MC_P^{1.1718})</td>
<td>0.998</td>
<td>(MC_K = 0.541 \cdot MC_P^{1.187})</td>
<td>0.998</td>
</tr>
<tr>
<td>(MC_P = 1.672 \cdot MC_K^{0.8417})</td>
<td>0.998</td>
<td>(MC_P = 1.6227 \cdot MC_K^{0.8517})</td>
<td>0.998</td>
<td>(MC_P = 1.6845 \cdot MC_K^{0.8407})</td>
<td>0.998</td>
</tr>
<tr>
<td>(MC_P = 0.4289 \cdot MC_H^{1.2305})</td>
<td>0.994</td>
<td>(MC_P = 0.3451 \cdot MC_H^{1.3047})</td>
<td>0.992</td>
<td>(MC_P = 0.4501 \cdot MC_H^{1.2157})</td>
<td>0.996</td>
</tr>
<tr>
<td>(MC_H = 2.0133 \cdot MC_P^{0.8079})</td>
<td>0.994</td>
<td>(MC_H = 2.2946 \cdot MC_P^{0.7605})</td>
<td>0.992</td>
<td>(MC_H = 1.9433 \cdot MC_P^{0.8193})</td>
<td>0.996</td>
</tr>
</tbody>
</table>

\[^{[a]}\] MC\(_K\) = kernel moisture content, % w.b.; MC\(_H\) = hull moisture content, % w.b.; MC\(_P\) = whole pod moisture content, % w.b.

Kernel, hull, and whole pod moisture contents were also characterized for 117 samples of runner type peanuts, collected from either the cross auger tube of a peanut combine or the inlet air duct to the basket. Of these samples, 97% exhibited kernel to hull moisture content ratios in excess of the kernel to hull moisture content ratios at equilibrated moisture conditions (fig. 5). Only four of the combine samples exhibited kernel to hull moisture content ratios less than that at equilibrium.
moisture conditions and three of these four were at hull moisture contents in excess of the range where equilibrium moisture contents were characterized.

![Graph showing Kernel moisture content vs. hull moisture content](image)

**Figure 5.** Kernel moisture content vs. hull moisture content for combine samples with respect to trend at equilibrated moisture conditions. The regression for combine samples may be suggestive of peanut drying pathway.

Figure 5 includes a “Drying Pathway”, which is a regression equation (eq. 1) predicting kernel moisture content as a function of hull moisture content \( (R^2 = 0.961) \) for the combine samples; equation 2 is a similar regression demonstrating whole pod moisture content as a function of hull moisture content \( (R^2 = 0.973) \). Equations 1 and 2 may be useful in estimating kernel and whole pod moisture contents as a function of a conceivably more accurately sensed hull moisture content, as demonstrated in this section. The data collected in this study is not sufficient to confirm the drying pathway in figure 5 and equations 1 and 2, but it is suggestive that such trends or such a set of trends might exist. This concept of drying pathways is supported when considering that peanuts must dry from the outside, inwards, i.e. the hull must dry to create a moisture gradient or drying force for the kernel. Because dug peanuts may be subjected to a wide range of environmental conditions, it is hypothesized that there are likely divergences from these drying pathways. Knowledge and characterization of these drying pathways may provide evidence for forecasting kernel moisture contents as functions of ambient conditions so that growers can better project when to combine after digging peanuts. Such forecasting could be valuable, especially during commonly exhibited periods around the peanut harvest when likelihood and frequency of rainfall events are high.

\[
MC_K = 19.435 \cdot \ln(MC_H) - 35.729 \quad (1)
\]

\[
MC_P = 18.748 \cdot \ln(MC_H) - 33.933 \quad (2)
\]

In-shell conductance measurements samples at equilibrium moisture content resulted in being a generally acceptable predictor of hull \( (R^2 = 0.874) \), kernel \( (R^2 = 0.868) \), and whole pod \( (R^2 = 0.871) \). Figure 6 demonstrates the relationships between moisture contents and conductance measurements for runner and virginia type samples combined, including only samples from the
equilibrated treatment. Moisture contents were found to be a third order polynomial function of the second logarithm (i.e. logarithm of logarithm, base 10) of conductance in units of Mho $\times 10^{10}$. Table 1 provides regression equations for hull, kernel, and whole pod moisture content predictions as functions of in-shell conductance. For the runner and combined runner and virginia subsets, conductance was better correlated to hull moisture content ($R^2 = 0.799$ and 0.874, respectively) than to kernel moisture content ($R^2 = 0.788$ and 0.868, respectively), as hypothesized since conductance was measured across the hull surface. This was not the case for the virginia subset where conductance better correlated with kernel moisture content ($R^2 = 0.923$) than with hull moisture content ($R^2 = 0.914$). In making comparisons between values demonstrated in table 2, the last column, demonstrating average absolute error of predictions as percentages of actual values, can be misleading when comparing virginia to runner predictions because the virginia subsets contained more samples at low moisture contents. Relationships were generally stronger between moisture content and conductance for virginia type samples than for runner samples, which may be explainable by pod size. Runner type pods are smaller than virginia type pods and therefore are more likely to require electrode-pod-pod-electrode interactions than simply electrode-pod-electrode interactions, making measurements on virginia type pods more consistent and repeatable. This hypothesis could be tested by repeating the tests with closer electrode spacing, which may result in improvement of the relationships between moisture content and conductance for runner type peanut.

![Graphs](image)

**Figure 6.** Hull (a), kernel (b), and whole pod (c) moisture contents with respect to the second logarithm (base 10) of in-shell conductance at equilibrium moisture conditions, including runner and virginia type (combined) datasets.
Table 2. Peanut moisture content prediction models as functions of in-shell conductance at equilibrated moisture conditions.

<table>
<thead>
<tr>
<th>Peanut Type</th>
<th>Moisture prediction equation$^{[0][8]}$</th>
<th>$R^2$</th>
<th>Error % w.b.</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runner and virginia</td>
<td>$MC = 920.23 \cdot \lambda^3 - 1107.9 \cdot \lambda^2 + 458.33 \cdot \lambda - 50.171$</td>
<td>0.874</td>
<td>1.6</td>
<td>13.0</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC = 609.46 \cdot \lambda^3 - 716.47 \cdot \lambda^2 + 299.55 \cdot \lambda - 29.568$</td>
<td>0.799</td>
<td>1.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC = 1022.8 \cdot \lambda^3 - 1228.7 \cdot \lambda^2 + 504.07 \cdot \lambda - 55.728$</td>
<td>0.914</td>
<td>1.6</td>
<td>16.8</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC = 680.46 \cdot \lambda^3 - 783.48 \cdot \lambda^2 + 320.56 \cdot \lambda - 36.36$</td>
<td>0.868</td>
<td>1.6</td>
<td>20.9</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC = 454.06 \cdot \lambda^3 - 496.77 \cdot \lambda^2 + 204.73 \cdot \lambda - 21.678$</td>
<td>0.788</td>
<td>1.8</td>
<td>12.5</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC = 802.84 \cdot \lambda^3 - 936.41 \cdot \lambda^2 + 380.92 \cdot \lambda - 43.66$</td>
<td>0.923</td>
<td>1.4</td>
<td>27.8</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC = 740.28 \cdot \lambda^3 - 864.93 \cdot \lambda^2 + 354.95 \cdot \lambda - 39.403$</td>
<td>0.871</td>
<td>1.6</td>
<td>16.8</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC = 494.9 \cdot \lambda^3 - 553.34 \cdot \lambda^2 + 228.17 \cdot \lambda - 23.147$</td>
<td>0.791</td>
<td>1.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC = 852.08 \cdot \lambda^3 - 1004.4 \cdot \lambda^2 + 410.45 \cdot \lambda - 46.2$</td>
<td>0.922</td>
<td>1.5</td>
<td>21.6</td>
</tr>
</tbody>
</table>

$^{[0]} \lambda = \log_{10}(log_{10}(G)); \text{ where } G = \text{conductance as Mho } \times 10^{10}$

$^{[8]} MC_H = \text{hull moisture content; } MC_K = \text{kernel moisture content; } MC_P = \text{whole pod moisture content}$

Correlations between moisture content and conductance were weaker when including data from all five treatments (equilibrated, 1 hr hull-dry, 10 min hull dry, 2 g hull-wet, and 4 g hull-wet), intended to generally represent the range of field conditions that might be experienced. These relationships can be seen in figure 7 and table 3, which includes both runner and virginia type peanut data. Conductance demonstrated a moderate correlation with hull moisture content ($R^2 = 0.762$), exhibiting poorer correlations with kernel moisture content ($R^2 = 0.558$) and whole pod moisture content ($R^2 = 0.650$). Application of the regression formulas provided in figure 7 resulted in average absolute prediction errors of 2.4% w.b. for hull moisture content, 3.2% w.b. for kernel moisture content, and 2.9% w.b. for whole pod moisture content as seen in table 3. Because it was observed in the combine samples that 97% of the samples exhibited hull to kernel moisture content ratios less than those at equilibrium, it was hypothesized that moisture prediction of combine samples as a function of conductance may be best represented by the two hull-dry treatments as seen in figure 8 and table 4.

![Graphs](image-url)
Figure 7. Hull (a), kernel (b), and whole pod (c) moisture contents with respect to the second logarithm (base 10) of in-shell conductance across all five treatments, including runner and virginia type (combined) datasets. In the regression equations provided, $\lambda$ represents $\log_{10}(\log_{10}(G))$, where $G$ represents conductance expressed as Mho x $10^{10}$.

Table 3. Peanut moisture content prediction models as functions of in-shell conductance across all five treatments.

<table>
<thead>
<tr>
<th>Peanut Type</th>
<th>Moisture prediction equation$^{[6][9]}$</th>
<th>$R^2$</th>
<th>Error % w.h.</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runner and virginia</td>
<td>$MC_H = 813.71 \cdot \lambda^3 - 935.13 \cdot \lambda^2 + 362.37 \cdot \lambda - 33.422$</td>
<td>0.762</td>
<td>2.4</td>
<td>18.6</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_H = 937.27 \cdot \lambda^3 - 1066.8 \cdot \lambda^2 + 403.47 \cdot \lambda - 37.198$</td>
<td>0.775</td>
<td>2.4</td>
<td>16.2</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_H = 713.48 \cdot \lambda^3 - 833.1 \cdot \lambda^2 + 332.88 \cdot \lambda - 30.968$</td>
<td>0.754</td>
<td>2.5</td>
<td>20.8</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC_K = 752.98 \cdot \lambda^3 - 846.78 \cdot \lambda^2 + 315.56 \cdot \lambda - 28.241$</td>
<td>0.558</td>
<td>3.2</td>
<td>37.0</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_K = 940.27 \cdot \lambda^3 - 1049.6 \cdot \lambda^2 + 381.1 \cdot \lambda - 34.714$</td>
<td>0.618</td>
<td>3.0</td>
<td>27.3</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_K = 578.3 \cdot \lambda^3 - 659.56 \cdot \lambda^2 + 255.88 \cdot \lambda - 22.369$</td>
<td>0.514</td>
<td>3.4</td>
<td>46.1</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC_P = 781.92 \cdot \lambda^3 - 886.21 \cdot \lambda^2 + 334.88 \cdot \lambda - 30.37$</td>
<td>0.650</td>
<td>2.9</td>
<td>27.3</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_P = 957.79 \cdot \lambda^3 - 1076.7 \cdot \lambda^2 + 396.16 \cdot \lambda - 36.384$</td>
<td>0.687</td>
<td>2.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_P = 619.26 \cdot \lambda^3 - 711.93 \cdot \lambda^2 + 279.68 \cdot \lambda - 24.992$</td>
<td>0.628</td>
<td>3.0</td>
<td>32.0</td>
</tr>
</tbody>
</table>

$^{[6]} \lambda = \log_{10}(\log_{10}(G));$ where $G =$ conductance as Mho x $10^{10}$

$^{[9]} MC_H =$ hull moisture content; $MC_K =$ kernel moisture content; $MC_P =$ whole pod moisture content
Figure 8. Hull (a), kernel (b), and whole pod (c) moisture contents with respect to the second logarithm (base 10) of in-shell conductance across only the two hull-dry treatments, including runner and virginia type (combined) datasets. In the regression equations provided, $\lambda$ represents $\log_{10}(\log_{10}(G))$, where $G$ represents conductance expressed as Mho x $10^{10}$.

Table 4. Peanut moisture content prediction models as functions of in-shell conductance across only the two hull-dry treatments.

<table>
<thead>
<tr>
<th>Peanut Type</th>
<th>Moisture prediction equation $^{[1][2]}$</th>
<th>$R^2$</th>
<th>Error % w.b.</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runner and virginia</td>
<td>$MC_{H} = 386.5 \cdot \lambda^3 - 434.95 \cdot \lambda^2 + 190.96 \cdot \lambda - 14.737$</td>
<td>0.835</td>
<td>1.9</td>
<td>18.7</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_{H} = 406.03 \cdot \lambda^3 - 452.67 \cdot \lambda^2 + 195.65 \cdot \lambda - 15.503$</td>
<td>0.896</td>
<td>1.8</td>
<td>18.5</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_{H} = 342.77 \cdot \lambda^3 - 360.61 \cdot \lambda^2 + 155.33 \cdot \lambda - 9.5794$</td>
<td>0.670</td>
<td>1.9</td>
<td>18.9</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC_{K} = 168.17 \cdot \lambda^3 - 297.09 \cdot \lambda^2 + 182.62 \cdot \lambda - 18.023$</td>
<td>0.731</td>
<td>2.1</td>
<td>22.7</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_{K} = 374.08 \cdot \lambda^3 - 521.68 \cdot \lambda^2 + 255.86 \cdot \lambda - 25.9$</td>
<td>0.834</td>
<td>1.8</td>
<td>20.3</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_{K} = -919.09 \cdot \lambda^3 + 844.04 \cdot \lambda^2 - 196.1 \cdot \lambda + 22.299$</td>
<td>0.647</td>
<td>2.3</td>
<td>23.3</td>
</tr>
<tr>
<td>Runner and virginia</td>
<td>$MC_{p} = 249.54 \cdot \lambda^3 - 350.23 \cdot \lambda^2 + 187.38 \cdot \lambda - 17.099$</td>
<td>0.778</td>
<td>2.0</td>
<td>20.8</td>
</tr>
<tr>
<td>Runner</td>
<td>$MC_{p} = 398.13 \cdot \lambda^3 - 511.29 \cdot \lambda^2 + 239.62 \cdot \lambda - 22.813$</td>
<td>0.867</td>
<td>1.7</td>
<td>19.4</td>
</tr>
<tr>
<td>Virginia</td>
<td>$MC_{p} = -466.94 \cdot \lambda^3 + 415.05 \cdot \lambda^2 - 71.595 \cdot \lambda + 11.074$</td>
<td>0.661</td>
<td>2.1</td>
<td>21.3</td>
</tr>
</tbody>
</table>

$^{[1]} \lambda = \log_{10}(\log_{10}(G))$; where $G$ = conductance as Mho x $10^{10}$

$^{[2]} MC_H$ = hull moisture content; $MC_K$ = kernel moisture content; $MC_p$ = whole pod moisture content
Prediction of kernel moisture contents from in-shell conductance measurements of the 42 combine samples was carried out using four methods. In method 1, kernel moisture contents were predicted using the equations provided for runner type peanut in table 3, because all combine samples were runner type peanut. In method 2, kernel moisture contents were predicted using the equations provided for runner type peanut in table 4, which used only the hull-dry treatments for model development. In method 3, hull moisture content was predicted using the equation predicting hull moisture content in table 4 and kernel moisture content was subsequently predicted as a function of hull moisture content using equation 1; i.e. conductance was used to predict hull moisture content and kernel moisture content was predicted as a function of the drying pathway referenced in figure 5. Method 4 was the same as that described for method 3, but using the hull moisture content prediction equation from table 4 (hull-dry treatments only) instead of that from table 3. Comparison of kernel moisture content prediction error from the four methods is shown in table 5. Methods 1, 2, and 3 generally over-predicted kernel moisture content. Method 3 demonstrated significantly less prediction error than method 1 and method 4 demonstrated significantly less prediction error than method 2, suggesting that use of the proposed drying pathway to predict kernel moisture content as a function of hull moisture content as a function of conductance may be a superior method to direct prediction of kernel moisture content as a function of conductance. Comparison of prediction errors of methods 1 and 2, and of methods 3 and 4 confirms that the hull-dry treatments were more representative of the field conditions observed in the combine samples, as expected.

| Table 5. Comparison of kernel moisture content mean prediction error[a] for combine samples across four methods. |
|-----------------------------------------------|---------------|---------------|---------------|
|-----------|---------------------|-----|-----------------|-----|
| 1         | 11.8                | A   | 46.1            | A   |
| 2         | 6.6                 | B   | 24.8            | B   |
| 3         | 6.3                 | B   | 24.2            | B   |
| 4         | 2.5                 | C   | 9.7             | C   |

[a] Method 1: Kernel MC predicted using runner equation from table 3 (all reconstituted samples)
Method 2: Kernel MC predicted using runner equation from table 4 (hull-dry treatments only)
Method 3: Kernel MC predicted using eq. 1 (drying pathway) as a function of hull MC prediction using runner eq. from table 3 (all reconstituted samples)
Method 4: Kernel MC predicted using eq. 1 (drying pathway) as a function of hull MC prediction using runner eq. from table 4 (hull-dry treatments only)

[b] Means with different letters are significantly different (student’s t-test, P < 0.05)

Conclusions

Models were developed demonstrating relationships between whole pod, kernel, and hull moisture contents for peanuts at moisture equilibrium. All of these models demonstrated strong correlations (R² > 0.985) and could be used to support estimation of two moisture content components when only one moisture content component is known. Kernel to hull moisture
content ratios for combine samples demonstrated higher values than those for equilibrated samples, presumably because of the nature of the drying taking place from outside-inward. A drying gradient must be established between the hull and the kernel, prior to moisture moving from the kernel towards the atmosphere.

Knowledge of the normal peanut drying pathway may be useful in developing predictive models for kernel moisture content as a function of environmental conditions. Furthermore, the normal drying pathway may be a useful tool for predicting kernel moisture content from hull moisture content measurements, because hull moisture content of a sample may be more accurately measurable than kernel moisture content. Of course, conditions may exist such which cause the ratio of kernel to hull moisture content to diverge from those along the normal peanut drying pathway, such as rain and heavy dew events. Within some unknown length of time after these events, prediction of kernel moisture content would be over-predicted as a function of hull moisture content using the normal drying pathway.

Models were developed for using conductance measurements for peanut moisture content prediction. Under all conditions analyzed here, these models proved to be more accurate in predicting hull moisture content than in predicting kernel or pod moisture content. Correlations between moisture content and measured conductance were higher for virginia type peanuts than runner type peanuts under equilibrated conditions. However, under all conditions analyzed here moisture content predictions for runner type peanuts were more accurate than those for virginia type peanuts. It is expected that size and spacing of electrodes on sensor assembly will be critical in optimizing accuracy for peanut moisture prediction using conductance measurements, although this was not tested here. Depending on accuracy required, this study shows that conductance may be a suitable low-cost method for peanut kernel moisture content determination, although its accuracy will be largely a function of environmental conditions observed.

References


