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Variable Depth Peanut Digger: Part II – Digging Loss Analysis

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Abstract. *A variable depth peanut digger was developed for use in assessing the ability to reduce digging losses as a function of digging blade angle and on-board remote sensing. Soil electrical conductivity (EC) data were used to divide a field into three zones, ranging from sand to clay texture. A computer controlled hydraulic top link was provided for adjustment of top link extension and therefore the digging angle. The optimal top link position was determined for each of the three zones by visual observation of the windrow and these three top link positions were applied in six replications across all three zones. Additional top link positions were conducted in the clay and sand soil zones, operating shallower than optimal in the sand texture zone and deeper than recommended in the clay texture zone. Average digging losses (dry basis) ranged from 156 to 556 kg ha^{-1} (138 to 496 lb ac^{-1}) in the sand texture zone, 330 to 854 kg ha^{-1} (294 to 761 lb ac^{-1}) in the medium texture zone, and 674 to 1,190 kg ha^{-1} (601 to 1,061 lb ac^{-1}) in the clay texture zone. Within each texture zone, the optimum indicated soil draft force, as indicated by a load shank positioned behind the center coulter, increased from coarse to fine soil textures. Hydraulic top link pressure indicated potential for use as an on-the-go feedback-based control for optimizing digging depth, with minimized digging losses occurring in the same range of pressure across two soil textures. A digging blade depth gauge was effective in on-the-go indication of blade depth and demonstrated potential for on-the-go digging angle prescription, but only where incomplete canopy coverage existed. The developed prototype demonstrated the potential for \$47 ha^{-1} (\$19 ac^{-1}) in yield loss savings with an estimated break-even payoff acreage of 109 ha (269 ac).*

Keywords. *Peanut, precision agriculture, digger, harvest losses, management zones, site-specific.*

Introduction

Applications of precision agriculture or variable rate technologies often result in increased production efficiencies, reduced inputs (energy, nutrient, chemical, etc.), and increased crop yields. Relative to the major grain crops and cotton, there have not been as many developments of precision agriculture applications specifically for peanut production. Developments in this area conceivably therefore stand to greatly improve. Implementation of Real Time Kinematic (RTK) navigation, auto-steering technologies have significantly reduced peanut harvest losses profitability and efficiency of peanut production caused by off-centered steering. One study indicated 186 kg ha^{-1} (166 lb ac^{-1}) yield loss for every 20 mm (0.79 in) deviation from row center (Ortiz et al., 2013).

Peanut digger research carried out at N.C. State University involved the development of a variable speed conveyor chain that adjusted to match the speed of the tractor, helping to reduce yield losses (Roberson, 2008). In this research the conveyor chain speed was synchronized with the tractor ground speed using variable rate sprayer technology and hydraulic controls. The overall goal was to reduce pods being ripped from the vines or shed due to bunching from speed of the chain being faster or slower, respectively, than the tractor speed. This improvement has yet to be added to commercially available peanut digger, although Amadas Industries offers a cab-mounted speed indicator, providing a visual output of conveyor chain speed in mph (Amadas Industries, Inc., 2011).

Most peanut losses occur during the digging, or inversion process (Bader, 2012). Generally, pod losses occur as a result of either weakened peg strength caused by disease and/or over-maturity (Chapin and Thomas, 2005; Grichar and Boswell, 1987; Thomas et al., 1983; Troeger et al.,1976), or physical actions of the digger which dislodge pods from plants. This makes time of digging and proper digger settings critical to reduce yield loss during the peanut harvest. Some loss is expected since a wide range of maturity exists across the pod profile. In order to harvest at the optimum time some pods are over-mature and loss of these is generally taken to be unavoidable. Soil conditions (friability) impact pod losses profoundly (Grichar and Boswell, 1987). Digging losses of 450 kg ha^{-1} (400 lb ac^{-1}) are not uncommon using the current digger design even when soil conditions are favorable. A twin row vs. single row digging loss study in virginia varieties conducted by Clemson University demonstrated average digging losses ranging from 650 to 1,350 kg ha^{-1} (580 to 1,200 lb ac^{-1}) dry weight, or about 9 to 22% of the total production for optimum digger depth settings (Kirk et al., 2013).

Proper digging angle is known to be dependent on soil texture, which can be highly variable throughout a field, especially in southeastern coastal plains soils where many peanuts in the U.S. are grown. To reduce yield losses created from improper digging angle, the operator must stop and change the length of the top link for the digger. In order to save time in adjustments, some peanut growers use the method of setting the digger blade depth to best match the finest or heaviest soil texture within field. However, this method of digger set up creates problems in coarser soil textures found within the field. Proper depth adjustment results in blades cutting the taproot about an inch below the pods. If peanuts are dug too deep, excessive soil builds up on blades causing losses by pushing the plants forward before the blade cuts the taproot. Even further losses can occur when pods have to ride over soil mounded on the blades.

Because the majority of profits or losses in peanut production can be attributed to digging decisions (Monfort, 2013), thorough knowledge of digging performance across a range of conditions and situations is critical to peanut production. The objectives of this project were to: quantify digging losses across different digging angles in three soil texture zones and evaluate various remote sensing technologies for use in digging angle prescription for minimization of digging losses.

Materials and Methods

Digging tests were conducted at Clemson University's Edisto Research and Education Center in Blackville, SC. The field used was approximately 6 ha (15 ac) with a substantial amount of soil texture variability, from 0 to 75% sand content, 5 to 85% silt content, and 0 to 50% clay content. The plots in the study were 12 m (40 ft) long with row spacing at 97 cm (38 in) and planted with Champs, a virginia peanut variety. Plots were dug with a KMC two row, three-point hitch mounted digger/shaker/inverter (Kelley Manufacturing Co., Tifton, Ga.) and a John Deere 7330 equipped with Trimble RTK AutoPilot™ (Trimble Navigation Limited, Sunnyvale, Cal.) following the same path from planting to minimize digging losses from row center deviation. Tillage was conventional and cultural practices and pest control followed Clemson Extension (Clemson University) recommendations. The digger blade was mounted so that the bevel was down. Care was taken to ensure that blades were not dull, conveyor speed was properly matched to ground speed, vines were not wrapping around shanks, and that blade angle and depths were set properly.

Soil EC mapping using a Veris 3100 (Veris Technologies Inc., Salina, Kans.) was used to spatially delineate three soil texture zones: sand, medium, and clay. The three zones were defined using an EC contour map (fig. 1) constructed in Farm Works Software (Trimble Navigation Limited, Sunnyvale, Cal.). To verify the validity of the use of EC data for delineation of soil texture zones within the digging depth of influence, soil samples were collected from the top 10 cm (4 in) at the time of digging. Hydrometer tests were conducted on the samples using the procedures outlined by Huluka and Miller (2014) to quantify the relative fractions of sand, silt, and clay.

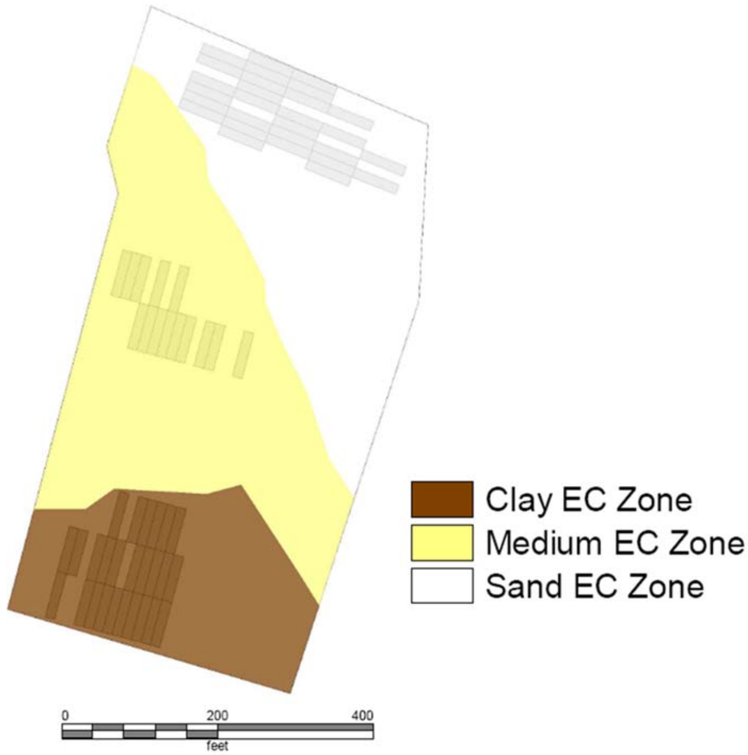

Figure 1. Soil texture zone delineation as a function of EC mapping and test plot locations within the zones.

The digger was set up for the proper digging blade angle within each of the three soil texture zones, providing a sand setting, a medium setting, and a clay setting. Assessment of proper blade angle and depth was performed as described in Kirk et al. (2013). Once the proper blade angle was determined for each of the three soil texture zones, all three of these blade angle settings were applied as digging treatments across each of the soil texture zones, giving nine treatments. An additional “too shallow” setting was applied in the sand zone and a “too deep” setting was applied in the clay zone, give a total of 11 treatments across the 3 soil texture zones (table 1). Six replicates were provided for each treatment and comparisons across treatments within each soil texture zone were performed using one-way ANOVA and Fisher’s LSD tests (α=0.05). Analysis of variance was not performed across data from different soil texture zones.

As described in Warner et al. (2014), the digger was equipped with a solenoid-controlled hydraulic top link, a linear potentiometer indicating extension length of the hydraulic top link, a hydraulic pressure transducer indicating digger reactant force on the top link, two soil draft force shanks, a digging blade depth gauge, and a data acquisition system collecting data at 10 Hz.

Digging loss data collection occurred five to six days after digging. To distinguish digging losses from combining losses, the windrow from each two-row plot in the study was gently lifted with pitchforks to a trailer, which carried the windrows to a stationary combine. The windrows were manually fed into the combine header and the entire yield from each plot was bagged and weighed. A sample for moisture analysis of approximately 1 kg (2 lb) was collected and weighed. Samples were oven-dried using ASABE S401.2 conventional oven method (ASABE, 2010).

A 0.6 m (2 ft) long by 2 row test area was randomly defined along the length of each plot. Above ground digging losses were collected and weighed from this area, independently quantifying sound pod losses from over-mature and diseased pod losses. Over-mature and diseased pods were not considered to be “true” digging losses because of their high propensity to be lost during harvest due to weak peg strength regardless of digger setup. Each test area was then excavated to a depth of 4 inches and the excavated soil was mechanically sieved (fig. 2) to collect the below ground losses. Below ground losses were weighed, once again distinguishing between sound, over-mature, and diseased pods. "True", or sound above and below ground losses were also oven-dried using ASABE S401.2 (ASABE, 2010). All losses reported in the results section are "true" or sound losses on a dry weight basis.

Figure 2. Digging loss sampling, showing excavated test area and soil sieve in operation.

Results and Discussion

Digging loss results indicated that digger-related yield losses are substantially affected by soil texture and digging depth, supporting the need for a variable digging angle prescribed as a function of soil texture (table 1). The greatest digging losses were experienced in the clay or fine texture soil, while the sandier or coarser texture soil sustained the lowest yield losses. The data within the sand and clay texture zones demonstrate numerically that an optimum digging blade angle exists, above and below which digging losses increase, with statistical significance of this evidence in the sand zone. It can be speculated that an optimum digging blade angle also existed for the medium texture, although the greatest prescribed angle in this study did not achieve enough depth to generate values demonstrating this.

Table 1. True digging losses, as the sum of above ground and below ground losses, for each soil texture zone across imposed digging angles.

Digger	Sand Zone			Medium Zone			Clay Zone		
Setting	lb ac^{-1}, d.b.		SD	lb ac^{-1}, d.b.		SD	lb ac^{-1}, d.b.		SD
Too Shallow	496	a	197	-		-	-		-
Sand	338	a,b	222	761	a	475	1061	a	372
Medium	138	b	59	518	a,b	258	765	a	436
Clay	417	a	293	294	b	95	601	a	244
Too Deep	-		-	-		-	986	a	673

These results demonstrate that absence of digging angle adjustment throughout a field with texture variability could substantially increase digging losses from those at the optimum angle. The data demonstrate that minimum digging losses for the test field were 386 kg ha^{-1} (344 lb ac^{-1}, d.b.) if the optimum digging angle was set for each of the three soil texture zones. As a worst case scenario, had the operator set the digging angle up for the sand texture zone and provided no top link adjustment throughout the field, losses would have more than doubled to 808 kg ha^{-1} (720 lb ac^{-1}, d.b.).

In the more likely event that the operator set the digging angle up for the finest soil texture in this field without additional adjustment in the field, digging losses would have been 490 kg ha^{-1} (437 lb ac^{-1}, d.b.), or 104 kg ha^{-1} (93 lb ac^{-1}) greater than optimum. At a conservatively assumed peanut value of \$441 mt^{-1} (\$400 ton^{-1}), savings indicated in this study from implementation of variable depth digger technology could realistically equate to \$47 ha^{-1} (\$19 ac^{-1}). Using a conservatively estimated retail cost for variable depth digger technology of \$5000, if made commercially available, the break-even payoff acreage for investment in the technology would be 109 ha (269 ac). It must be recognized that soil texture variability exhibits different extremes in different fields; the field used for this study exhibited a relatively high degree of variability. While digging loss savings from implementation of variable depth digger technology should be expected in most instances, the magnitude of savings will differ with the magnitude of soil variability.

As demonstrated in figure 3, the numerically optimum digging depth in the sand texture zone occurred at the digging angle setting prescribed for the medium texture zone. As indicated by the blade depth gauge, the blade depth for this optimum depth was 8.4 ± 0.8 cm (3.3 ± 0.3 in). While losses at this setting can be said to be significantly less than those at the too shallow and clay settings, they are not statistically different from losses at the sand setting, which demonstrated an indicated blade depth of 6.4 ± 0.8 cm (2.5 ± 0.3 in). Relationships between digging losses and blade depth for the medium and clay texture zones could not be developed for this study due to the problems associated with the blade depth gauge in full canopy coverage, discussed in Warner et al. (2014). If the blade depth gauge can be redesigned to work in across all levels of canopy coverage, these data for the sand texture zone indicate that the blade depth gauge can be a viable prescription basis for on-the-go variable control. Furthermore, if the optimum digging blade depth is similar across soil textures, then EC and texture management zones would not be required for variable digging angle prescription.

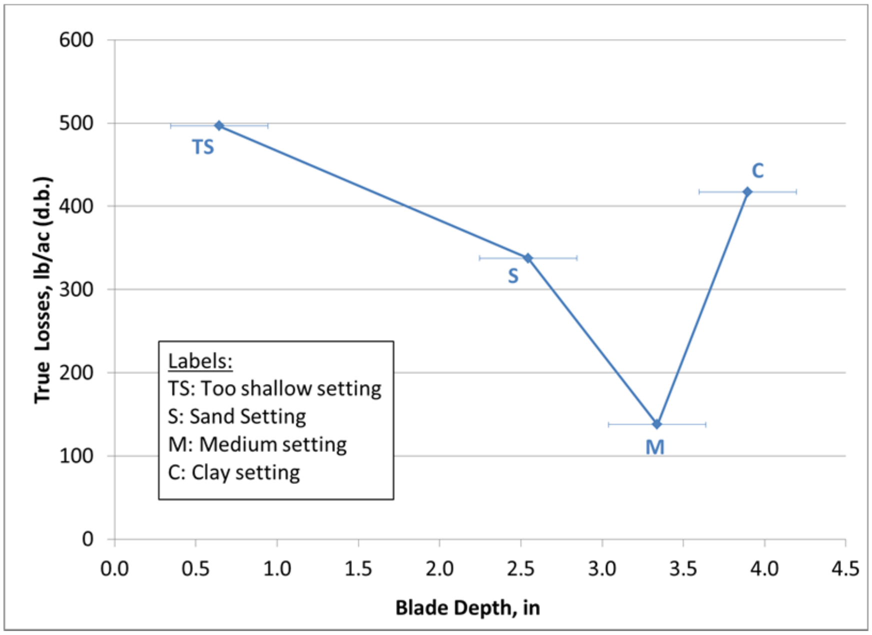

Figure 3. True digging losses as a function of indicated blade depth in the sand texture zone. Error bars represent ± ½ LSD.

Figure 4 shows true digging losses as a function of the front soil draft force, from the instrumented shank mounted on the front of the digger behind the center coulter. It is reiterated that the mounting position of the front soil draft force shank caused the shank to change depth with the digging blade, increasing indicated force at greater depths. For clarity and due to problems with the geometry of the load shank mounting configuration discussed in Warner et al. (2014), the point associated with the too deep setting in the clay texture zone is not included here. The data suggest that the soil draft force associated with the optimum digging loss setting increases from coarse to fine texture soils. While this trend is suggestive that soil draft force sensing could be useful as a prescriptive tool, the high degree of variability observed in soil draft force sensing within each treatment would make on-the-go, continuously variable adjustment on the basis of soil draft force coarse and imprecise.

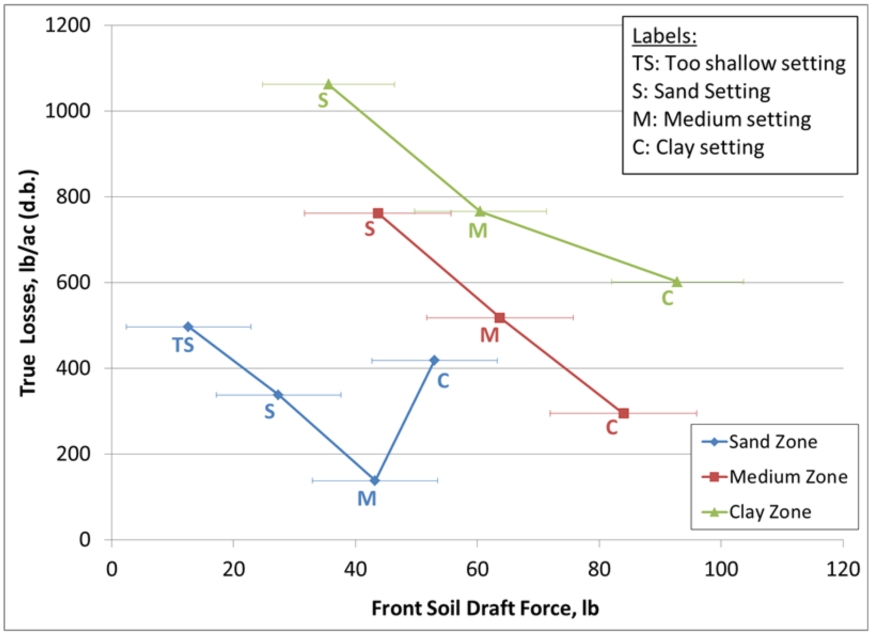

Figure 4. True digging losses as a function of soil draft force at the front load shank, behind the center coulter. Error bars represent ± ½ LSD within soil texture zones.

The reactant force imparted on the top link during digging, as measured by the hydraulic pressure transducer, produced less variable data within each treatment than the soil draft force sensing (fig. 5), with statistical differences between each treatment within each soil texture. As discussed in Warner et al. (2014), a sensor malfunction resulted in loss of top link pressure data for the sand soil texture. The data show that the top link pressure at the optimum digging angle was not statistically different between the medium and clay texture zones. This is in contrast to the relationship demonstrated between soil draft force at optimum digging angle and soil texture, increasing from coarse to fine textures. While further study must be conducted to confirm or refute, this suggests that an optimum top link pressure may be definable for a given machine and field condition, which is universally applicable across all soil textures for that field and machine. This would allow on-the-go continuously variable digging angle adjustment in the absence of an EC map or knowledge of soil texture.

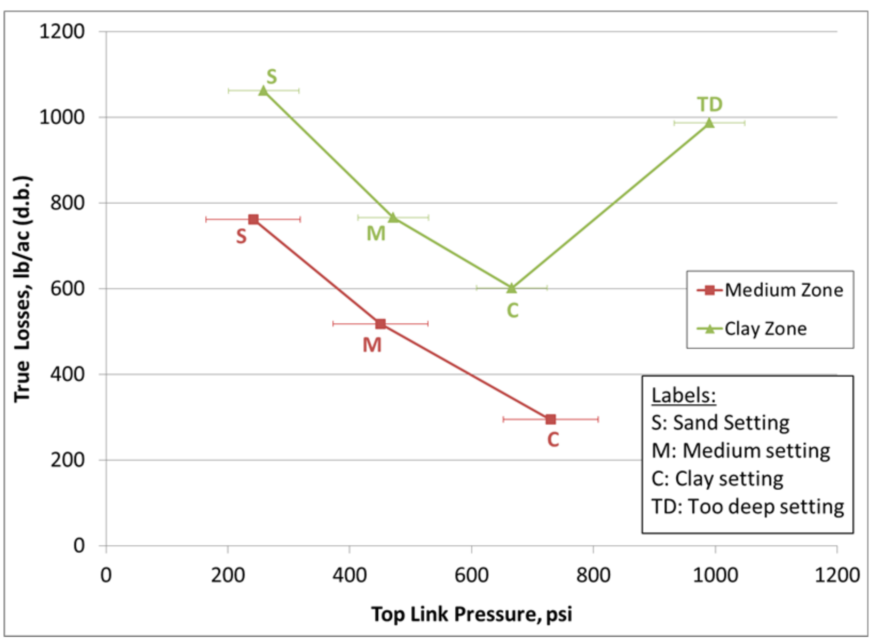

Figure 5. True digging losses as a function of top link hydraulic pressure. Error bars represent ± ½ LSD within soil texture zones.

Conclusions

A variable depth peanut digger was developed and tested to evaluate several digging angle prescription methodologies relative to digging losses incurred. Proof of concept was demonstrated in the developed system, which allows the operator to prescribe a top link extension length for each of three soil texture zones. A map-based control system was developed with the ability to adjust top link length to the prescriptions, according to GPS position and therefore soil texture zones.

Among the sensing technologies developed and tested for on-the-go, feedback-based prescription, the blade depth gauge and top link pressure showed the most potential for suitability. Both of these sensing technologies demonstrated potential to be employed in the absence of EC and soil texture management zone development, although further study is required to confirm. Soil draft force sensing demonstrated too much variability across reps within treatments to be a stable feedback basis for digging angle prescription.

Future work should be directed at reducing variability in digging loss data by sampling larger test areas or multiple test areas per plot. Redesign of the blade depth gauge is required to allow the gauge to ride along the soil surface regardless of canopy effects. Testing in different fields with various degrees of soil texture variability should be conducted in order to evaluate the repeatability of the results presented here. Investigation should also be conducted to quantify digging losses associated with blade depth adjustment through means of lifting three-point hitch arms, with no top link adjustment.

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References

Amadas Industries, Inc. 2011. *AMADAS Digger-Inverters.* MAN108. Suffolk, Va.

ASABE Standards. 2010. S410.2: Moisture Measurement—Peanuts. St. Joseph, Mich.: ASABE,

Bader, M. 2012. Bulletin 1087: Peanut Digger and Combine Efficiency. Athens, Ga.: University of Georgia Cooperative Extension. Retrieved from http://www.caes.uga.edu/applications/publications/files/pdf/B%201087_2.PDF

Chapin, J. W., Thomas, J. S. 2005. Effect of fungicide treatments, pod maturity, and pod health on peanut peg strength. *Peanut Science* 32:119-125.

Grichar, W. J., and T. E. Boswell. 1987. Comparison of no-tillage, minimum, and full tillage cultural practices on peanuts. *Peanut Science* 14:101-103.

Huluka, G. and R. Miller. 2014. Particle size determination by hydrometer method. In F. J. Sikora (Ed.), *Southern Cooperative Series Bulletin No. 419: Soil Test Methods From the Southeastern United States*, (pp.180-184). Southern Extension and Research Activity Information Exchange Group - 6.

Kirk, K. R., H. F. Massey, W. S. Monfort, J. S. Thomas, B. Jordan, and W. B. Schmidt. 2013. Single row vs. twin row digging losses for two virginia type peanut varieties. ASABE Paper No. 1620957. St. Joseph, Mich.: ASABE.

Monfort, Scott. 2013. Peanut money-maker production guide. Circular 588. Clemson, S.C.: Clemson University Cooperative Extension.

Ortiz, B. V., K. B. Balkcom, L. Duzy, E. van Santen, and D. L. Hartzog. 2013. Evaluation of agronomic and economic benefits of using RTK-GPS-based auto-steer guidance systems for peanut digging operations. *Precision Agric.* 14:357–375.

Roberson, G. 2008. Improving harvesting effectiveness for peanut diggers. NC State University Department of Biological and Agricultural Engineering. Retrieved from http://www.bae.ncsu.edu/people/faculty/gtrobers/roberson-posters/Improving-peanut-diggers-poster.pdf

Thomas, R. J., R. E. Pettit, R. A. Taber, and B. L. Jones. 1983. Peanut peg strength: Force required for pod detachment in relation to peg structure. *Peanut Science* 10:97-101.

Troeger, J. M., E. J. Williams, and J. L. Butler. 1976. Factors affecting peanut peg attachement force. *Peanut Science* 3(1):37-40.

Warner, A. C., K. R. Kirk, J. S. Thomas, W. S. Monfort, J. W. White, S. A. Brantley, J. S. Peele, H. F. Massey, Y. J. Han, and J. D. Compton. 2014. Variable depth peanut digger: Part I - Design and Testing. ASABE Paper No. 1914163. St. Joseph, Mich.: ASABE.