Impact of Ground Speed and Conveyor Speed on Peanut Digging

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ABSTRACT. A study was conducted at Edisto Research & Education Center to quantify the effects of ground speed and conveyor speed on peanut digging losses using 2-row Amadas and KMC peanut diggers. The study was directed at providing producers with recommendations for peanut digger setup and operation to maximize yield recovery; previous studies at Edisto REC have focused on quantifying digging losses as a function of digging depth. Proper peanut digger setup and operation is critical to profitability—while manufacturers provide recommendations for proper setup and ground speed, there exist few published studies assessing these recommendations. In this study experiments were conducted to compare digging losses for four ground speeds (3.2, 4.8, 6.4, and 8.0 kph) at 100% relative conveyor speed and five relative conveyor speeds (80%, 90%, 100%, 110%, and 120%) at 4.8 kph ground speed; tests were conducted independently for the two diggers using Virginia-type peanuts. For both diggers, digging losses increased as a function of ground speed with no significant difference in the 3.2 and 4.8 kph treatments. Results for the conveyor speed tests were consistent between the two diggers, with significantly higher losses at the 120% relative conveyor speed, but no significant differences across the other conveyor speeds. For the conditions of this test, results suggested that optimum ground speeds for peanut digging should not exceed 4.8 kph and that a range of conveyor speeds is acceptable, but conveyor speed should not exceed 110% of ground speed.

Keywords. Peanut, digger, speed, harvesting losses, groundnuts.
Introduction

Digger setup and operation, along with proper timing often has a greater impact on yield recovery than any other aspect of peanut production; put simply, more revenue can be made or lost during digging than during any other field operation from seedbed preparation to combining (Anco, 2017). Even with the greatest care in proper setup and maintenance, digging losses in 2013 through 2016 Clemson studies (Kirk et al., 2013; Kirk et al., 2014; Warner et al., 2014; Warner et al., 2015) on virginia type peanuts were demonstrated to average 308 kg ha\(^{-1}\) (275 lb ac\(^{-1}\)) under good soil moisture conditions (3-7% volumetric moisture content) and 386 kg ha\(^{-1}\) (344 lb ac\(^{-1}\)) under dry soil moisture conditions (1.6-2.4% volumetric moisture content). In all of these studies, the numbers reported were as dry weight and only those losses considered to be mechanically induced; over-mature and diseased pod losses were not included in the numbers reported.

Conveyor Speed

Amadas Industries (Suffolk, Virg.) and Kelley Manufacturing Co. (KMC, Tifton, Ga.) suggest that the conveyor speed should be matched to your forward travel speed (Amadas, 2011; Peanut Grower, 2017). Bader (2012) suggests that conveyor speed should be set slightly faster than forward speed to avoid pileup of vines ahead of pickup and Roberson (2016) states that conveyor speed should be synchronized to avoid dragging and snatching of plants, with optimum shaker speed slightly faster than ground speed. It is generally assumed that conveyors traveling too fast tend to prematurely rip the vines from the soil, which increases pod losses. It is also assumed that conveyors traveling too slowly tend to cause the vines to bunch up at the bottom of the conveyor, causing excessive agitation of the vines and therefore increased pod losses. A review of the literature revealed little published studies evaluating yield losses as a function of conveyor speed relative to ground speed; optimal peanut digger operation for yield recovery is therefore limited to assumptions and general observations. Roberson (2008) conducted a study with a modified digger to automate chain speed to match ground speed with a variable rate controller; test results demonstrated substantially lower digging losses for a digger equipped with the automated control system as compared to those for a conventional digger.

A simple way to set the conveyor speed used by many growers is to adjust it until the inverted windrow falls slightly (about 0.6 m or 2 ft) down-field from where the plants were growing. This can be assessed by placing a flag outside of the digger path at the beginning of a set of rows and observing the location of the end of the windrows relative to the flag. This only works well if the digger is engaged at full operating and ground speed prior to entering into the peanut plants. If the end of the windrow is several feet farther into the field than the flag, then the conveyor speed is too slow. If the end of the windrow is equal in position to or behind the flag, then the conveyor is too fast. Many current models of Amadas diggers provide an interface with a digital readout of the conveyor speed in mph, so that hydraulic flow rate can be easily adjusted to match conveyor speed to travel speed.

Fastidious operators may desire a more accurate method of matching conveyor speed to ground speed, which can be conducted through the following simple calculation and setup. First, the total length of the conveyor must be determined, which is simply equal to the rod spacing on the conveyor multiplied by the total number of rods. The conveyor length can then be converted to units of feet. Next, the operating ground speed can be converted to units of ft min\(^{-1}\), which can be calculated by multiplying ground speed (mph) by 88, a factor derived from 5280 ft mi\(^{-1}\) divided by 60 min hr\(^{-1}\). The conveyor speed (rpm) required to match ground speed is equal to the ground speed (ft min\(^{-1}\)) divided by the conveyor length (ft). From the conveyor speed (rpm), the conveyor cycle time can be calculated as 60 sec min\(^{-1}\) divided by the conveyor speed (rpm). This value represents the number of seconds required for one full revolution of the conveyor. For accuracy, it may be convenient to multiply this value by 10, to determine the number of seconds required for 10 full revolutions of the conveyor. Once required conveyor cycle time is determined, setting the conveyor speed is simple. A flag of masking tape or other convenient marker should be placed on one of the conveyor rods. With the tractor rpm set for normal operating speed, the tractor in park, the digger lifted, and all personnel clear of moving parts, the conveyor should be engaged and a stopwatch can be used to observe the time to make 10 full revolutions. If this time is less than what was calculated in the previous step, then the conveyor is too fast; if this time is greater than what was calculated in the previous step, then the conveyor is too slow. Adjustment on a pto conveyor drive requires reduction or increase in pto speed. Adjustment on a hydraulic conveyor drive requires adjustment of hydraulic flow rate to the appropriate circuit.

Ground Speed

Amadas (2011) suggests “starting speeds” of 4.0 to 4.8 kph (2.5 to 3 mph) and KMC (Peanut Grower, 2017) suggests ground speeds of 4.8 to 5.6 kph (3 to 3.5 mph). Bader (2012) suggests digging speeds of 5.6 to 8.0 kph (3.5 to 5 mph) and Roberson (2016) indicates that heavy pod losses may result at ground speeds in excess of 6.4 kph (4 mph). KMC further suggests that digging too fast causes bunching and that digging too slowly pulls vines apart, pulling off pods. The larger pod virginia type peanuts have more surface area per pod and therefore higher drag forces, so they are more likely to be ripped from the peg resulting in losses. Because of this, it is reasonable to assume that lower speeds should be used for virginia type peanuts, as compared to those used for runner type and other, smaller pod peanuts. The differences in speeds
recommended by Amadas, KMC, Bader, and Roberson may be related to the areas in which the companies and Extension engineers reside, with Amadas and Roberson being located in areas where virginia type peanuts are predominately grown, and KMC and Bader being located in areas where runner type peanuts are predominately grown, although this is only speculation. It is, however, reasonable to assume that suitable ground speeds for digging runner type peanuts are likely higher than those for digging virginia type peanuts.

In ideal situations, digging ground speeds should be economically optimized. Very little literature exists demonstrating the effects of ground speed on peanut digging, but it is reasonable to expect that optimum digging speeds will vary as a function of conditions, increasing for more favorable conditions and decreasing for less favorable conditions. Theoretically, economically optimum digging speed should: decrease with increasing pod size, increase with increasing sand content, increase with increasing organic matter, and decrease with decreasing soil moisture content. However, weather conditions at harvest and required timeliness of digging with respect to other farming operations must also be considered, which make generalizations about economically optimum digging speeds challenging to make. Table 1 can be used as a general guide for selecting digger speeds as a function of timeliness alone; it assumes a field efficiency (digging time divided by total time in field) of 85% and a row width of 96 cm (38 in.).

<table>
<thead>
<tr>
<th>Speed [kph]</th>
<th>Capacity [ha hr⁻¹]</th>
<th>Time [hr/10ha]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 [2.5]</td>
<td>1.3 [3.3]</td>
<td>7.7 [3.1]</td>
</tr>
<tr>
<td>4.8 [3.0]</td>
<td>1.6 [3.9]</td>
<td>6.4 [2.6]</td>
</tr>
<tr>
<td>5.6 [3.5]</td>
<td>1.9 [4.6]</td>
<td>5.4 [2.2]</td>
</tr>
<tr>
<td>6.4 [4.0]</td>
<td>2.1 [5.2]</td>
<td>4.7 [1.9]</td>
</tr>
<tr>
<td>7.2 [4.5]</td>
<td>2.4 [5.9]</td>
<td>4.2 [1.7]</td>
</tr>
<tr>
<td>8.0 [5.0]</td>
<td>2.6 [6.5]</td>
<td>3.7 [1.5]</td>
</tr>
</tbody>
</table>

To provide supporting background relevant this study, a survey was conducted of S.C. peanut growers in 2017 at regional peanut production meetings. Among the 33 respondents, typical peanut digging ground speeds were reported: across runner and virginia type peanut, combined, the predominant (37.5% of respondents) digging speed for runner and virginia peanuts was in the range of 4.8 to 5.6 kph (3.0 to 3.5 mph); in runner type peanut the predominant (41.4% of respondents) digging speed was in the range of 4.8 to 5.6 kph (3.0 to 3.5 mph); and in virginia type peanut the predominant (47.4% of respondents) digging speed was in the range of 4.0 to 4.8 kph (2.5 to 3.0 mph). Overall average reported digging speeds were 5.0 kph (3.1 mph) for runner and virginia type peanut combined, 5.0 kph (3.1 mph) for runner type peanut, and 4.8 kph (3.0 mph) for virginia type peanut. Average reported digging speed for runner type peanut was not significantly different from that for virginia type peanut (Student’s t-test, \( \alpha = 0.05 \)).

Objectives

The objectives of this study were to: (1) evaluate the effects of conveyor speed on virginia type peanut digging losses and (2) evaluate the effects of ground speed on virginia type peanut digging losses.

Materials and Methods

Two 2-row diggers were used for the tests reported here: an Amadas ADI-238 with a belt conveyor and a KMC 238 with a chain conveyor. Tests were not designed to allow comparisons of the two diggers; the tests were conducted at Clemson University’s Edisto Research and Education Center in Blackville, SC. The field used for the tests on the Amadas digger was approximately 0.9 ha (2.3 ac) and the field used for the tests on the KMC digger was approximately 1.1 ha (2.7 ac). Both fields were planted in virginia type peanuts; the field used for testing on the Amadas digger was planted in a Champs variety and the field used for testing on the KMC digger was planted in a Wynne variety. The fields were adjacent to one another and both fields ranged from sand to loamy sand soil textures. Peanuts were dug with a John Deere 7330 equipped with Trimble RTK AutoPilot™ (Trimble Navigation Limited, Sunnyvale, Cal.) following the same path from planting to harvesting. Tillage was conventional and cultural practices and pest control followed Clemson University Extension recommendations. Care was taken to ensure that blades were not dull; conveyor speed was properly set for each treatment, and that blade angle and therefore depth for each treatment were set consistently.

Soil electrical conductivity mapping using a Veris 3100 (Veris Technologies Inc., Salina, Kans.) was used to identify three different soil texture zones within the two fields. The three zones were defined using a contour map of the shallow EC (0-30 cm, 0-12 in.) constructed in Farm Works Software (Trimble Navigation Limited, Sunnyvale, Cal.). Soil volumetric moisture content was taken at the time of digging using the Decagon 10HS Large Volume Soil Moisture sensor (Decagon...
Devices Inc., Pullman, Wash.); volumetric soil moisture content was 4 ± 1%.

Treatments were dug in 122-152 m (400-500 ft) long strips with row spacing at 96 cm (38 in.). A total of eight digging treatments were applied in each of the two fields: 3.2 kph (2.0 mph) ground speed at 100% conveyor speed, 4.8 kph (3.0 mph) ground speed at 100% conveyor speed, 6.4 kph (4.0 mph) ground speed at 100% conveyor speed, 8.0 kph (5 mph) ground speed at 100% conveyor speed, 1.8 kph (3.0 mph) ground speed at 80% conveyor speed, 1.8 kph (3.0 mph) ground speed at 90% conveyor speed, 1.8 kph (3.0 mph) ground speed at 110% conveyor speed, and 1.8 kph (3.0 mph) ground speed at 120% conveyor speed. Conveyor speed is expressed as percent of respective ground speed. Three replicate strips of each treatment were provided arranged in randomized block designs within each field. Strips used as traffic for spraying operations were excluded from the study. Comparisons across treatments were performed using one-way ANOVA and student's t-tests (α=0.05).

Digging loss data collection occurred six days after digging. Two digging loss sample areas were defined for each strip at distances equal to 1/3 of the strip length from each end of the strip; sampling areas were 1.2 m (4 ft) long by 2 rows. To distinguish digging losses from combining losses, a 1.8 m (6 ft) section of windrow above the sample area was gently lifted with a custom built windrow lifter. This allowed individuals to collect above ground digging losses from the defined sample area prior to combining (Figure 1a). Prior to excavation, combine discharge and possible combining losses were removed from the test areas using a leaf blower. Once each test area was clear of debris, it was excavated to a depth of at least 10 cm (4 in.) and the excavated soil was mechanically sieved to collect the below ground losses (Figure 1b). Above and below ground digging losses were oven-dried using ASABE S401.2 conventional oven method (ASABE, 2012). Over-mature and diseased pods were dried and weighed separately from the other digging losses, as they were not considered to be mechanical digging losses because of their high propensity to be lost during harvest regardless of digger setup due to weak peg strength. Mechanical losses were defined as those pods where evidence existed demonstrating that some of the exocarp was ripped from the pod. Diseased and over-mature pods were defined as those where the peg was present but broken or frayed.

Results and Discussion

Results are divided into conveyor speed tests and ground speed tests for each digger. As previously noted, because the two diggers used in the study were tested in different fields planted in different peanut varieties, comparisons across diggers are not valid.

Conveyor Speed Tests

As discussed, conveyor speed tests were conducted at a ground speed of 1.8 kph (3 mph), with conveyor speed treatments expressed as a percentage of ground speed. There were no visible differences in windrows or inversion quality across conveyor speeds for either digger, as seen in Figures 2a and 2b. Both diggers demonstrated similar trends in digging loss as a function of conveyor speed (Table 1), demonstrating no significant difference in digging loss across the four lower conveyor speeds tested and a significant increase in digging losses at the 120% conveyor speed. These data may provide support to the theory that a conveyor speed substantially higher than the ground speed may increase digging losses through the mode of pulling vines from the before the digger blade has the opportunity to sever the tap root of the plant. The suggestion that a conveyor speed substantially lower than the ground speed may increase digging losses as a result of the vines bunching at the bottom of the conveyor was not observed in this test, although it is possible that a conveyor speed lower than 80% of the ground speed must be established prior to seeing this effect. These results support both manufacturers’ recommendations that conveyor speed should be set to match ground speed but additional tests across a wider range of digging conditions should be conducted to provide a greater understanding of the relationships involved. Digging losses
directly translate to yield recovery losses; at a peanut price of $441 MT\(^{-1}\) ($400 ton\(^{-1}\)), these data suggest that improperly adjusted conveyor speed could result in revenue losses of approximately $50-200 ha\(^{-1}\) ($20-80 ac\(^{-1}\))

Figure 2. Visual appearance of windrows across tested conveyor speeds (noted above each image) at 1.8 kph (3 mph) ground speed for the Amadas digger (a) and the KMC digger (b).

Table 2. Comparison of digging losses across conveyor speed treatments for each digger. Means with different letters within each digger group are significantly different (student's t-test, p < 0.05).

<table>
<thead>
<tr>
<th>Conveyor Speed</th>
<th>Amadas Digger</th>
<th>KMC Digger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Digging Losses</td>
<td>St.Dev.</td>
</tr>
<tr>
<td>80%</td>
<td>223.3 B</td>
<td>66.5</td>
</tr>
<tr>
<td>90%</td>
<td>256.2 B</td>
<td>122.2</td>
</tr>
<tr>
<td>100%</td>
<td>233.9 B</td>
<td>98.3</td>
</tr>
<tr>
<td>110%</td>
<td>248.5 B</td>
<td>79.0</td>
</tr>
<tr>
<td>120%</td>
<td>377.9 A</td>
<td>97.8</td>
</tr>
</tbody>
</table>

Ground Speed Tests

Visual observations of the windrows demonstrated little to no notable differences in inversion quality across tested ground speeds for the Amadas digger (fig. 3a), although the KMC digger (fig. 3b) demonstrated marginal inversion at a ground speed of 6.4 kph (4 mph) and poor inversion at a ground speed of 8.0 kph (5 mph). Inversion could have likely been improved for the KMC digger at the higher ground speeds if the conveyor speed was reduced, but the pre-defined protocol for the test called for setting the conveyor speed equal to the ground speed for these tests. The poor inversion for the KMC digger at the higher ground speeds was visually observed to be a result of the slope of the conveyor, which is steeper than that of the Amadas digger. Both diggers lift the peanuts vines to a similar height prior to inversion, but the total Amadas conveyor length was measured to be 4.37 m (14.35 ft) and the total KMC conveyor length was measured to be 3.34 m (10.97 ft). The reduced slope of the Amadas conveyor from the approximately 30% longer conveyor allowed the vines a sufficient opportunity to fall at the end of the conveyor to the inverter rotors. At the higher ground and conveyor speeds, the trajectory
of vines on the KMC conveyor was too steep to allow the vines sufficient time to fall to the inverter rotors at the end of the conveyor; at the 8.0 kph (5.0 mph) speed few if any of the vines contacted the inverter rotors, which is attributed to the poor inversion observed in Figure 3b.

![Figure 3a](image1.png)

![Figure 3b](image2.png)

Figure 3: Visual appearance of windrows across tested ground speeds (noted above each image) at 100% conveyor speed for the Amadas digger (a) and the KMC digger (b).

Table 3 shows comparisons of digging losses across ground speeds for each digger. It is reiterated that comparisons between the diggers cannot be made due to the experimental design of the tests, with the tests being conducted in different fields and different varieties. For both diggers there was a numerical increase in average digging loss as a function of ground speed. For the Amadas digger, there was no significant difference in digging losses between 3.2 and 4.8 kph (2.0 and 3.0 mph), but with significantly higher losses observed at the two higher ground speeds. A simple linear regression model applied to this data suggests that there was an additional 156 kg ha\(^{-1}\) digging losses for each kph above 4.8 kph (223 lb ac\(^{-1}\) for each mph above 3.0 mph). The trend was similar for the KMC digger, with significant differences in digging losses at the three lower ground speeds tested. The KMC data for this study demonstrated an additional 192 kg ha\(^{-1}\) digging losses for each kph above 3.2 kph (192 lb ac\(^{-1}\) for each mph above 2.0 mph).

<table>
<thead>
<tr>
<th>Ground Speed (kph)</th>
<th>Amadas Digger</th>
<th>KMC Digger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Digging Losses kg ha(^{-1})</td>
</tr>
<tr>
<td>3.2 (2.0)</td>
<td>6</td>
<td>165.1</td>
</tr>
<tr>
<td>4.8 (3.0)</td>
<td>6</td>
<td>233.9</td>
</tr>
<tr>
<td>6.4 (4.0)</td>
<td>6</td>
<td>555.9</td>
</tr>
<tr>
<td>8.0 (5.0)</td>
<td>5</td>
<td>732.6</td>
</tr>
</tbody>
</table>

Table 3. Comparison of digging losses across ground speed treatments for each digger. Means with different letters within each digger group are significantly different (student's t-test, p < 0.05).

Assuming custom operations digging costs of $74 ha\(^{-1}\) ($30 ac\(^{-1}\)), a digging speed of 6.4 kph (4 mph), a digger width of 5.8 m (19 ft), and an 85% field efficiency, variable costs for peanut digging can be estimated to be equal to $234 hr\(^{-1}\). Dividing this hourly variable cost of digger operation by the field capacity of a peanut digger operating at a particular speed suggests machinery costs on a per unit area basis. Because field capacity increases with speed, these machinery costs per unit area decrease with increasing ground speeds. The digging loss regression models discussed in the previous paragraph...
were applied along with the machinery costs discussed here to calculate a total peanut digging cost as a function of ground speed, as seen in Figures 4a and 4b. For digging virginia type peanut in the conditions in the two fields used for this study, Figure 4 demonstrates an optimum economic ground speed of about 4.8 kph (3.0 mph) for the Amadas digger and less than or equal to 3.2 kph (2.0 mph) for the KMC digger.

Figure 4. Peanut digging costs for the Amadas (a) and KMC (b) diggers, demonstrating total digging costs: equal to the sum of digging loss costs, as suggested for the conditions demonstrated in this study and the estimated machinery costs as calculated from typical custom machinery rates. Assumed parameters: 6-row digger, 96 cm (38 in.) rows, $441 MT⁻¹ ($400 ton⁻¹) peanut price, and 85% field efficiency.

Conclusion

Results from this study suggest that it is best to lag (> 80% of ground speed) or match conveyor to ground speed for both the Amadas and KMC diggers in virginia type peanut. Conveyor speeds of 120% of ground speed for both diggers resulted in significantly increased digging losses, which could amount to an additional $50-200 ha⁻¹ ($20-80 ac⁻¹) in lost revenue. For the conditions present in this test, digging losses for both diggers were significantly higher at higher ground speeds. For the Amadas digger an additional 156 kg ha⁻¹ digging losses were experienced for each kph above 4.8 kph (223 lb ac⁻¹ for each mph above 3.0 mph) and for the KMC digger an additional 192 kg ha⁻¹ digging losses were experienced for each kph above 3.2 kph (192 lb ac⁻¹ for each mph above 2.0 mph).

Because increasing ground speeds result in reduced operating time, digging machinery costs per unit area decrease with increasing ground speeds. This relationship between digging machinery costs and ground speed was used along with the digging loss costs as functions of ground speed observed in this study to suggest optimum ground speeds for profitability. Optimum ground speed for profitability minimizes the sum of digging loss costs and digging machinery variable costs. For the conditions in this study optimum ground speeds were 4.8 kph (3 mph) and 3.2 kph (2 mph) for the Amadas and KMC diggers, respectively.

As discussed, digging losses will vary as a function of digging conditions. The results demonstrated in this study are not necessarily the same as those that would be observed under different conditions. However, it is likely that the general trends in digging losses as functions of conveyor speed and ground speed demonstrated in this study would be similar under varying conditions. More work similar to this study needs to be done to optimize peanut yield recovery across a range of digging conditions and peanut types.

Acknowledgements

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References
