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Sources of Peanut Digging Losses and Strategies to Reduce Losses During Inversion

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SOURCES OF PEANUT DIGGING LOSSES AND STRATEGIES TO REDUCE LOSSES DURING INVERSION

Loren Samenko

SOURCES OF PEANUT DIGGING LOSSES AND STRATEGIES TO REDUCE LOSSES DURING INVERSION

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Plant and Environmental Sciences

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by
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Accepted by:
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ABSTRACT

Presented research was conducted at Clemson University's Edisto Research and Education Center to quantify harvest related losses associated with the effects of peanut digger blade geometry, the effects of the peanut digger inversion assembly, and the effects of vine load on digging and strategies to address vine load. Three studies were performed to determine the potential losses incurred during the digging processes; various harvest metrics were analyzed to quantify the effects of the treatments. Five objectives guided the presented research. Objectives of the effects of peanut digger blade geometry study investigated the impact of blade geometry and blade aggression on recovered yield, blade depth, and stability. Objectives of the effects of the peanut digger inversion assembly included an investigation of the effects of the current digger inversion assembly on recovered yield and above ground losses. The effects of vine load on digging and strategies to address vine load studies research was guided by three objectives, which address vine load control methods, mechanical vine load control strategies, and methods to monitor vine load conditions within the digger. Digging operations utilized a two-row automated depth controlled KMC 2-38 peanut digger while digging the peanut variety FloRun 331 in 2018 and 2019, and Emery in 2020; all plots were planted and dug with the use of autosteer. Tests were conducted in two-row plots of consistent lengths, respective to the study year. Recovered yield data was collected in 2019 and 2020 studies using a 2-row plot combine. Combine settings were consistent throughout the duration of harvest. Results from the testing demonstrated significantly improved recovered yields in the effects of peanut digger blade geometry study; in the most adverse digging conditions tested recovered yield increased by 532 kg ha^{-1} (475 lb ac^{-1}). The inversion assembly was found to result in significantly increased above ground mechanical losses by as much 23 kg ha^{-1} (21 lb ac^{-1}) when peanuts were dug at 4.0 kph (2.5 mph). The effects of vine load on digging and strategies to address vine load study indicated recovered yield improvements of 275 kg ha^{-1} (245 lb ac^{-1}) when vine mass was reduced with the plant growth regulator Apogee. Further, reduced total above ground losses were found with standard rod spacing treatments and conveyor speeds of 85% to 100% of ground speeds independently. The investigation of methods to monitor vine load conditions determined that the application of vine speed sensing significantly detected speed differences across harvest conditions. The data suggested substantial effects on digging depth, depth stability, recovered yield, above ground losses, and inversion ratings as a function of the various treatments defined, and a quantification of these effects are reported.

DEDICATION

I would like to dedicate this thesis to my parents, J.R. and Trinia Samenko, my brother Andrew Samenko, grandparents, Breanna Kimbrell, family and friends. Without each of you, I would not be where I am today. I am forever thankful for all that you have done for me on this journey.

ACKNOWLEDGMENTS

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CHAPTER ONE:

INTRODUCTION

In the late 1950's, peanut production began to vastly change with the introduction of windrow harvesting. Windrow harvesting greatly reduced labor requirements of peanut production, resulting in a shift from the previous stack-pole harvest method (Wright et al., 1979). The introduction of the digger/shaker/windrower fueled rapid change and research throughout the late 1950's, 1960's, and early 1970's in the peanut industry. In 1971, a digger/shaker/inverter was patented; the design culminated a set of blades, a conveyor and inversion assembly to effectively dig, invert, and windrow peanut plants for harvest of the pods (Paulk, 1971). This basic design is still being used and manufactured today with relatively few design changes. The newly designed, commercially available digger/shaker/inverter's advantageous performance over previous methods in the peanut industry was documented early within its experimental and market life. During this period, various studies documented the digger/shaker/inverter's benefits in drying performance, windrow uniformity and reductions in harvest losses over the previously available diggers and harvest methods (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968). The digger/shaker/inverter will be referred to herein-after as "peanut digger" or "digger", as is common in industry. In the 50 years since the digger's introduction, a review of current literature reveals limited amounts of research have been conducted on the performance of the digger despite its widespread use in the United States. Some studies have investigated the digger's overall performance on peanut harvest. Various studies suggest the potential losses during harvest are high during the peanut digging process and influenced by factors such as crop health and condition, maturity, disease and weed pressure, digger setup and condition, digger speed, operation precision, environmental and soil conditions (Bader, 2012; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; Roberson et al., 2014; Warner et al., 2015; Wright et al., 1991; Young et al., 1982).

In the United States peanut industry, the digger/shaker/inverter has been the dominant design of diggers used (Paulk, 1971). A 2017 survey of South Carolina peanut growers indicated of the 33 respondents, 100% used a digger/shaker/inverter style digger (Dr. K. Kirk, Clemson University, personal communication, 22 February 2017). This design initially relies on a set of blades to initiate soil failure, sever the tap root of the peanut plant, and provide lift to remove the plant from the soil (the digging process). Once displacement from the soil occurs, a conveyor system lifts and agitates the plant to remove excess soil from the plant (the shaking process). As the plant offloads from the conveyor system, it is introduced to the inversion system where plants are inverted and windrowed (the inversion process). Increased losses associated with recovered yield can be introduced throughout the digging, shaking, or inversion processes if performance is not optimized for the given conditions (Amadas, 2011; Kirk et al., 2017; Peanut Grower, 2017; Warner et al., 2014; Zerbato et al., 2017).

Mechanical losses induced by the digger during peanut harvest result in a reduction of recoverable yield; pods detached during digging can no longer be recovered by the harvester. Mechanically induced losses can be categorized as losses resulting from weakened pegs (gynophores); pegs are the plant structure that attach the peanut pod to the plant during growth and development, excessive damage to the pegs results in detachment of the pod from the plant by the mechanical system involved in harvest (Chapin et al., 2005). Current research indicates that harvest and mechanical losses are influenced by a range of factors including the soil moisture content, ground speed, vine load and suboptimal digger setup for conditions (Amadas, 2011; Azmoodeh-Mishamandani et al., 2014; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; KMC, 2014; Roberson, 2021; Warner et al., 2015). The prevalence of mechanically induced losses during digging was presented in a four-year Clemson University study on Virginia type peanuts; mechanical losses ranged from 58 kg ha^{-1} (52 lb ac^{-1}) to 785 kg ha^{-1} (700 lb ac^{-1}) under good soil moisture conditions (3-7% volumetric moisture content) and proper digger setup and operation (Kirk et al., 2021), indicating the large potential for losses during the digging process.

Additional research was conducted on the importance of digger setup and operation in respect to harvest losses. This research offered insight into losses as a function of ground speed; losses increased at a rate of 192 kg ha^{-1} kph^{-1} when diggers were operated at ground speeds over 3.2 kph (276 lb ac^{-1} mph^{-1} above 2 mph) (Kirk et al., 2017). The study suggested that higher than optimal digging ground speeds could potentially cost growers upwards of \$85 ha^{-1} kph^{-1} when digging above 3.2 kph (\$55 ac^{-1} mph^{-1} above 2 mph), assuming a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}). Advancements in digger integrated precision technology, such as the 2008 N.C. State University developed automatic chain control digger which adjusts chain (conveyor) speed with respect to tractor ground speed, reported reduction of above and below ground losses and showed the potential for industry improvement (Roberson, 2008). The aforementioned study conducted by Kirk et al. (2017) also identified increased losses as large as 446 kg ha^{-1} (500 lb ac^{-1}) with excessive conveyor speeds (120% of ground speed). Yields were maximized at the 100% conveyor setting under normal vine conditions and the study showed yield benefits of lagging conveyor speeds (70-80% of ground speed) in rank vines, or vines with excessive growth (Kirk et al., 2017).

In a 2013 Southeastern study, it was demonstrated that proper digging angle as a function of soil texture resulted in the reduction of harvest losses across variable soil textures; suboptimal digging angle resulted in yield detriments as large as 357 kg ha^{-1} (400 lb ac^{-1}), equating to revenue losses of \$176 ha^{-1} (\$71 ac^{-1}) (Kirk et al., 2014). A 2020 Clemson University study indicated the importance of operator maintenance of row center during digging operations; row center deviation was shown to detriment yield by 72.6 kg ha^{-1} cm^{-1} (165 lb ac^{-1} in.$^{-1}$) (Samenko et al., 2020). These studies have investigated various digger-specific operational methods and management techniques during the digging process. These contributions along with many others have helped to better define the relationship between the operation of digging and the recovery of peanut yield and have quantified losses incurred during this process.

As noted, proper digger operation can be among one of the most influential variables on yield recovery during peanut harvest (Bader, 2012; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; Roberson et al., 2014; Samenko et al., 2020; Warner et al., 2014; Warner et al., 2015; Wright et al., 1991), affirming the value of knowledge gained from the study of digging operations. These studies indicate a large potential for improved yield recovery during the digging process, through improvement and understanding of the digger. Studies such as these can provide growers with impactful information, resulting in significant increases in yield and harvest efficiency. However, a void in the availability of information is present, which compartmentalizes digger-related losses as a function of digger process and components. Further studies on the interactions of digger components and their individual impacts on yield recovery is needed. For example, studies of quantification of the proportion of yield losses attributed to the blade versus those from the inversion assembly. An understanding of the losses attributed to individual digger components may better direct subsequent research and development focused on mitigating mechanically induced harvest losses.

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CHAPTER TWO:

EFFECTS OF PEANUT DIGGER BLADE GEOMETRY ON YIELD AND LOSSES

Introduction

The digger blade assembly's main function is severing of the taproot, initiating failure of the soil structure to reduce drag forces on the pod and creating lift to remove the plant and pods from the soil (Bader, 2012; Kirk et al., 2013; Kirk et al., 2021; Young et al., 1982). The general performance of the assembly is reliant upon proper digging depth and is affected by soil texture and moisture. Literature indicates when optimized digging depth is achieved it allows for the blade to sever the peanut taproot roughly an inch below the pods (Kirk et al., 2014; Warner et al., 2014a). Proper digging depth, in a given set of soil conditions, is maintained through the adjustment of the implement's three-point hitch center link, or top link. Retracting (shortening) the top link establishes a more aggressive digging angle, and a deeper blade depth is achieved. Extending (lengthening) the top link reduces digging angle and a shallower blade depth is achieved. Proper digging depth is imperative to optimal yield recovery. Too shallow of a digging depth can result in losses occurring from impact of pods with the blades, or plants severed above the pod zone entirely. Additionally, losses can occur from too deep of a digging depth when insufficient soil failure is provided by the blade, resulting in plants being pulled from the soil (Kirk et al., 2014; Roberson et al., 2021; Warner et al., 2014a). Kirk et al. (2014) demonstrated that improper top link adjustment as a function of soil texture could result in yield losses up to 448 kg ha^{-1} (400 lb ac^{-1}).

Although proper digging angle can typically be achieved through top link adjustment, instances of insufficient top link adjustment exist. In the circumstance that a more aggressive blade angle is needed than that provided by top link adjustment, industry recommends the addition of a wire shim to raise the back of the digger blade and/or changing the orientation of the blades so that the bevel is facing upwards (Amadas, 2011; KMC, 2014; Roberson, 2021). These practices increase blade aggression or angle to take on ground and achieve proper depth. These recommendations are likely based on observations, adaptations from similar agricultural tillage tools, and experience, rather than direct findings in peanut digger research as indicated by the limited amount of literature available.

Maintenance of proper digging depth is dynamic and dependent upon top link length adjustment and soil parameters in a given harvest condition. These variables define the efficiency and ability of the blades to perform their functional task. When considering the functions of the blade assembly in conjunction with the soil, the complexity of the blade mechanics is revealed. To provide a general understanding of the achievement of proper digging depth, one must understand interaction between the soil and the digger blade. The digger blade interaction with the soil can be generalized into three independent force systems which include the weight force (digger) acting on the blade itself, the soil forces acting on the blade, and the forces acting between the digger and the tractor (draft) (Gill et al., 1968). In the absence of acceleration, these forces can be considered to be in equilibrium; therefore, any action has a dependent reaction. These reactions are functions of specific and highly variable soil parameters and the blade-soil interaction, including soil strength, moisture content, blade angle, blade shape, etc. (Gill et al., 1968). Omer et al. (2001) investigated the effects of blade shape, blade angle, depth and digging speed on blade-soil mechanics, reporting that draft forces, soil disturbance, and peanut digging losses were directly correlated to the treatment variables.

To optimize digging depth, the relationship between the soil forces and the blade must be considered in respect to resultant blade depth. For a given top link position and therefore digging angle, heavier soils (higher clay content soils) generally result in shallower blade depths than blade depths in lighter soils (lower clay content soils); conversely, lighter soils result in deeper blade depths at given digging angle than heavier soils (Amadas, 2011; Kirk et al., 2014; KMC, 2014). When digger operation and setup remain constant, depth variability, and therefore digger performance as discussed in Kirk et al. (2014), can be attributed to the system of soil forces related to each specific soil type. The blades' ability to effectively induce failure of the soil structure and lift the plant requires variable forces to be applied for different soils and soil conditions. At any given harvest condition, the forces applied during digging must be constrained to achieve desired failure of soil structure along with the prevention of failure in the peanut peg. Various studies and theories in soil mechanics have labeled strength (of soil structure) as a dynamic property of soil and variable under many environmental and physical factors (Gill et al., 1968). General agreement in literature provides that soil strength increases with increased clay content but decreases with increased soil moisture and organic content (Gill et al., 1968; Rowe et al., 1961; Watts et al., 1998).

Subsequently, it could be expected that a greater application of force in the vertical direction would be needed to reach sufficient failure of soil structure and provide sufficient lift, therefore loosening the soil sufficiently and achieving proper digging depth for heavier soils (those with higher clay content), lower moisture contents, and lower organic matter contents. Conceivably, this could be achieved through blade angle adjustment, although this would also increase blade depth, in effect moving the resultant soil failure zone farther from the pod zone if applied to the current design of the peanut digger, which utilizes manual adjustment of the implement's three-point hitch center link, or top link. The research which has been conducted has primarily investigated the relationship between the digger blades achievement of proper digging depth and harvest losses; the findings of these studies suggest positive interactions between the optimization of digging blade depth through top link adjustment as a function of soil type, as well as indicate significant effects of the interaction of the digger blade depth in specific soil structures on peanut yield (Kirk et al., 2014; Warner et al., 2014a; Warner et al., 2014b; Warner et al., 2015; Zerbato et al., 2017). Omer et al. (2001) investigated the relationship between draft force and blade angle independent to digger top link adjustment, finding increased draft forces with increased blade angle. Research is needed to determine the direct impact of blade angle or aggression during peanut digging that allows for a quantification of losses as a function of blade angle and independent of other digger systems and processes (i.e., conveying and inversion).

This study quantified the effects of peanut digger blade geometry on peanut yield loss in various digging conditions. The objectives of the study were to investigate the impact of blade aggression and blade geometry on yield recovery and digging depth by manipulation of blade bevel orientation and the practice of shimming blades to increase blade inclination angle. Effects were evaluated in a range of harvest conditions including heavy and light soil types and varying late leaf spot management.

Materials and Methods

In 2020 tests conducted at Clemson University's Edisto Research and Education Center, the effects of digger blade geometry on recovered yield in a variety of harvest conditions were studied. The objectives of the study were to investigate the impact of blade aggression with respect to blade geometry by manipulation of blade bevel orientation and the practice of shimming blades and therefore manipulating blade angle. The tests evaluated the blade geometries' effects on recovered yield, blade stability and depth in a range of harvest conditions. Harvest conditions included the presence of heavy and light soil types and various disease incidence with two levels of late leaf spot (*Nothopassalora personata*) control. The investigated factors consisted of four blade geometry treatments: bevel down, bevel up, use of a small shim (0.318 cm [0.125 in]), and use of a large shim (0.635 cm [0.250 in]).

Each of the four blade geometries was tested in a distinct region of a field, one region with light textured soil (95% sand content) and one with heavier soil (91% sand content). The experimental design of the blade geometry test utilized two independent, randomized block designs (RBD) for the light and heavy soil texture areas, each RBD with five replications. The main treatment factor was comprised of the four blade geometry treatments previously outlined. Blade bevel down was prescribed as the least aggressive orientation, followed by bevel up, then the small shim, and the large shim being defined as the most aggressive. For the blade bevel up and blade bevel down treatments, the blades were directly mounted to the frog assembly with the bevel oriented in the corresponding position. The shimmed blade geometries were achieved by placing a "small" 0.318 cm (0.125 in) or "large" 0.635 cm (0.25 in) piece of round steel stock behind the stove bolts, between the blade and the frog. Blade bevel was oriented in the bevel down position for the shimmed treatments. Figure 2.1 illustrates the blade geometry treatments as described. Disease pressure control was tested with two levels of late leaf spot control based on fungicide application schedules defined at planting (Table 2.1) based on Clemson University Extension guidelines.

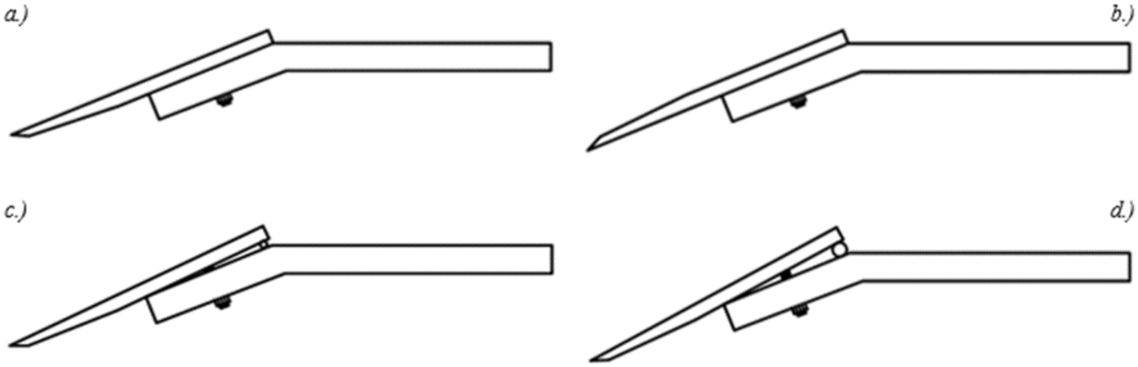

Figure 2.1. Blade geometry treatments. a.) Blade bevel down b.) Blade bevel up c.) Small shim (0.318 cm) d.) Large shim (0.625 cm)

Table 2.1. Blade geometry test fungicide application schedule.

Late Leaf Spot Control Treatment	30 DAP[a]	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP
Low Level	None	Bravo	Convoy[c]	Bravo	Bravo + Convoy	None	None
High Level	Bravo[b]	Bravo	Bravo + Convoy	Bravo	Bravo + Convoy	Bravo	Bravo

[a] DAP- Days after planting.

[b] Bravo- Chlorothalonil (479 g ai L^{-1} [4.0 lb ai gal^{-1}]) applied at 1.8 L ha^{-1} (1.5 pt. ac^{-1}) (Syngenta Crop Protection, LLC, Greensboro, NC.)

[c] Convoy- Flutolanil (431.4 g ai L^{-1} [3.6 lb ai gal^{-1}]) applied at 2.3 L ha^{-1} (2.0 pt. ac^{-1}) (Nichino America, Inc., Wilmington, DE.)

The field utilized for this study, D3BC, was located at Clemson University's Edisto Research and Education Center in Barnwell County, South Carolina. The blade geometry test was conducted in two conventionally tilled, non-irrigated areas of approximately 0.3 ha (0.7 ac) in the two soil texture areas. D3BC is predominantly comprised of Barnwell Loamy Sand soils (91% sand content) in the heavy soil texture test area and Wagram Sand (95% sand content) in the light soil texture test area (Soil Survey Staff, 2021). A Virginia type peanut variety, Emery, was planted in early June of 2020 on 97 cm (38 in.) row spacing and managed utilizing Clemson University Extension guidelines (Figure 2.2). Sets of eight consecutive test rows were alternated between four border rows; the borders were used for traffic (spraying) passes throughout the season and excluded from the test to avoid soil compaction factors in the test. Experimental plots in the study consisted of two 20 m (65 ft) long rows. Digging operations were performed on November 9th using a Case Maxxum 140 with Trimble RTK Autopilot™ (Trimble Navigation Limited, Sunnyvale, CA.). A two-row automated depth controlled (Warner et al., 2014a) KMC 2-38 peanut digger (Kelley Manufacturing Co., Tifton, GA.) was used in all plots while digging.

Figure 2.2. Blade geometry test plots, showing relative positions of the light (red) and heavy (blue) soil type areas in field D3BC.

All plots were sprayed at 60 and 90 days after planting (DAP) with 2.3 L ha^{-1} (2 pt ac^{-1}) of Convoy. The late leaf spot control treatment levels of low or high control were randomly assigned to each plot as discussed before; when applied, application rates of 1.8 L ha^{-1} (1.5 pt ac^{-1}) of Bravo were used. To achieve prescribed treatments levels of late leaf spot control (low and high), application frequency was manipulated as specified in Table 2.1. Digging was executed at a consistent engine speed in the same gear range to maintain a relatively constant ground speed of 4.0 kph (2.5 mph). Conveyor speed was set to match the ground speed (100% conveyor speed equated to a conveyor speed of 4.0 kph [2.5 mph]). The blade geometry treatments were dug in order of aggression as previously defined, beginning with blade bevel down. At the conclusion of digging each blade geometry treatment, the operator disassembled and reassembled the blade assembly in accordance with the prescribed blade geometry. The peanut rows were oriented in a south-west to north-east direction, and the operator maintained consistent driving directions for each plot, always driving towards the south-west.

Recovered yield data was collected for each plot using a 2-row Hobbs combine (Amadas Industries, Suffolk, Va.). Combine operations were conducted on December 3 - 4, 2020. The delay of 24 – 25 days between combining and digging was due to the slowed drying of the windrows because of rainfall and cool ambient temperatures during this time. Conditions at combining could be defined as poor for peanut harvest. Consistency was maintained during combining operations, all plots within a replication were exposed to consistent drying conditions and harvested on the same date. The 2-row Hobbs plot combine used in this test was developed by Clemson University to monitor yields within a research plot (Kirk et al., 2012). This combine is equipped with a weighing basket, which provides a measurement of total recovered yield within each plot; the combine was set to consistent machine settings for all plots. Throughout combining operations, samples of approximately 2 kg (2 lb) were collected from the combine weighing basket for a moisture content analysis, composited across test plots. Samples were collected on both December 3 and 4. These moisture contents were utilized to report recovered yield on a dry basis. The samples used to determine moisture content were oven dried using a modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure; due to the reduced heating capabilities of available dryers, modification of the ASABE S410.3 Alternate Whole Pod Method was necessary. Recovered yields reported herein are reported as dry weights. Average moisture content was thought to sufficiently describe the wet basis moisture content for all peanuts harvested, and adequate for correction of wet yield weights to dry yield weights.

In addition to yield data, digger depth was recorded for the length of each plot at a 10Hz frequency. The two-row automated depth KMC 2-38 peanut digger used was equipped with a solenoid-controlled hydraulic top link. The control system maintains a target depth specified as a percentage of allowable depths based on feedback from a rotary potentiometer attached to a depth gauge wheel, which indicates the position of the digger blade relative to ground level. Further discussion of this system is described by Warner et al. (2014a) and Warner et al. (2015). In addition to the feedback-based depth control, the digger was equipped with a data acquisition system which logged depth at a frequency of 10Hz through a model 1018 interface kit (Phidgets Inc., Calgary, Alberta, Canada). Digger blade depth was recorded and maintained to a target depth throughout the test with software developed in Visual Basic 2010 using Microsoft Visual Studio Express 2010 (Microsoft Corp., Redmond, Wash.).

The data logs were georeferenced in Farm Works Software (Trimble Navigation Limited, Sunnyvale, Cal.) where GPS position data and corresponding values for digger depth were identified and constrained to respective plot boundaries. For the duration of the test, the targeted depth was set to 58% of maximum digging depth with a ±4% tolerance range, and a 1s averaging time was used for feedback control of depth. The digging depth percentage range is defined at the lower limit as (0%) at full extension of the depth gauge or where the diggers blade is entirely above ground, and the upper limit of the range (100%) can be defined as the maximum allowed travel for the depth gauge or maximum digging depth. The tolerance range specified earlier defines the allowable travel from the targeted depth prior to initiation of top link adjustment. The mean digging depth in percentage of allowable travel was determined for each plot. Additionally, calculations to determine standard deviation of digging depth within each plot were performed and utilized as an indication of depth stability.

Statistical analyses were conducted using one-way ANOVA and Students t-test (α=0.05) to make comparisons between digger geometry treatments for recovered yield, mean digging depth, and standard deviation of digging depth. Statistical analyses were performed in JMP pro v.14.1.0 statistical software (SAS Institute Inc., Cary, NC.). The following standard procedure for statistical analysis was carried out for all analyses. Data sets were confirmed to be from a normal distribution using the Shapiro-Wilk w-test for goodness of fit (α= 0.05). If rejected for normalcy, transformations were performed with box-cox transformations (Ott et al., 2010), otherwise (i.e. dataset was found to be from the normal distribution) the transformation step was omitted. Once data sets were normalized (as required), an outlier analysis was performed, and outliers were excluded from the analysis on a basis following constraints of Tukey's 1.5 inter quartile range rule (Ott et al., 2010). A one-way ANOVA and Student's t-test were performed upon completion of the listed procedures. In addition to the comparisons discussed above, analysis of subsequent effects of blade geometry on recovered yield, digging depth and blade depth standard deviation were performed by grouping of individual treatment factors (split factors) within the test (effect of blade geometry broken out by each treatment factor).

Results and Discussion

Yield Recovery

The 2020 test quantified the effects of blade geometry on recovered yield in a variety of digging conditions. Across all blade geometry treatments average recovered yield ranged from 3,017 kg ha^{-1} (2,692 lb ac^{-1}) to 3,173 kg ha^{-1} (2,831 lb ac^{-1}) and revealed no significant yield effects overall, in the absence of interactions. The overall impact of blade bevel geometry on recovered yield, with no accountability for interactions is summarized in Table 2.2. A large amount of variability in recovered yields was present between treatments. This in part may have been due to the advanced maturity of the peanuts which were dug 160 days after planting, potentially reducing recovered yield to that of a typical harvest year. Investigation of recovered yield as a function of blade geometry by soil type and by level of late leaf spot control revealed significance at the α=0.10 level. Additional, statistically insignificant, but consistent trends in datasets were identified during analysis. It has been documented in the field of peanut research that the lack of significant differences, in the presence of evident trends, may be more impactful at full scale production levels. In a multi-year, multi-state peanut study investigating the effects of chemical growth regulator on recovered peanut yield recovery, significant differences were reported for larger on-farm experiments, despite lack of significance for the same treatments at the plot-based research level (Studstill et al., 2020). Studstill et al. (2020) proposed that on-farm experiments handle the inherent variability present in peanut research better than plot-based research.

Table 2.2. Mean recovered peanut dry yield (kg ha^{-1}) as a function of blade geometry across soil types and levels of late leaf spot control. ($F_{3,76}=0.143, p=0.9339$)

Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Bevel Down	20	3061	A	188.5
Bevel Up	20	3017	A	188.5
Small Shim	20	3029	A	188.5
Large Shim	20	3173	A	188.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Average recovered yield ranged from 1,870 kg ha^{-1} (1,669 lb ac^{-1}) to 2,403 kg ha^{-1} (2,144 lb ac^{-1}) for the four blade geometry treatments in heavy soil types, under low levels of late leaf spot control, notably the toughest digging conditions presented in this study. The overall effect of blade geometry on recovered yield in heavy soils under low levels of leaf spot control was significant at the α=0.10 level. Table 2.3 provides a summary of these results and indicates that the mean recovered yield for the large shim treatment, presumably the most aggressive blade geometry, had significantly higher mean recovered yield. The large shim treatment achieved a 532 kg ha^{-1} (475 lb ac^{-1}) greater recovered yield than the worst performing blade geometry (blade bevel up). Considering a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}) an increase in revenue of \$235 ha^{-1} (\$95 ac^{-1}) could be expected from the indicated yield benefit when proper blade geometry is used. No statistical differences in recovered yield were present between the bevel down, small shim and the large shim treatments.

Comparisons between the large shim and blade bevel down (presumably least aggressive blade treatment) or industry standard recommend blade geometry for normal digging applications (Amadas, 2011; KMC, 2014) in heavy soils and low levels of late leaf spot control showed the large shim blade geometry resulted in 347 kg ha^{-1} (410 lb ac^{-1}) higher recovered yield valued at \$153 ha^{-1} (\$62 ac^{-1}) over that for the blade bevel down geometry, although no significant differences in yield recovery were found between the two treatments. It should be noted that the harvest conditions implemented in the plots under low level of leaf spot control treatments resulted in increased disease pressure. Increased disease pressure and heavy soil conditions were found to increase the prevalence of harvest related losses by Grichar et al. (1998) and Kirk et al. (2014). Therefore, proper digger setup is more important in these conditions. The results found here are in agreement with these findings and indicate the importance of proper digger blade aggression.

Table 2.3. Mean recovered peanut dry yield (kg ha^{-1}) as a function of blade geometry for low level of late leaf spot control in heavy and light soils.

		Heavy Soil Type $F_{3,16}$ = 1.3496, p= 0.2937				Light Soil Type $F_{3,16}$ = 0.2453, p= 0.8634		
Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping α=0.05[a] (α=0.10)[b]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Bevel Down	5	2056	A (AB)	194.4	5	2741	A	200.3
Bevel Up	5	1871	A (B)	194.4	5	2829	A	200.3
Small Shim	5	2207	A (AB)	194.4	5	2591	A	200.3
Large Shim	5	2403	A (A)	194.4	5	2748	A	200.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

[b] Treatments with the same letter indicate no significant differences (α=0.10).

Analysis of the recovered yield as a function of blade geometry only indicated significance in the low level of late leaf spot control in heavy soils. Although mean recovered yields as a function of blade geometry were not found to be statistically significant in other conditions investigated, notable trends were found within the data, as discussed below. Means comparison of the blade geometry effects on recovered yield established a trend in all test condition treatments of increased blade aggression over the blade bevel down geometry provided some degree of mean numerical yield benefit. In no conditions did the blade bevel down geometry result in the lowest mean recovered yield of the four blade geometry treatments, performing better than at least one of the imposed blade geometry treatments in all cases. The large shim geometry provided the highest numerical average recovered yield in six out of eight combinations of treatment factors. A general trend in yield was observed as a function of blade geometry in the heavy soil type (Table 2.4), with a positive relationship between the mean recovered yield and blade aggression through shimming. In comparison, recovered yields in the heavy soil type for the two shimmed blade geometry treatments average 93 kg ha^{-1} (83 lb ac^{-1}) valued at \$41 ha^{-1} (\$17 ac^{-1}) higher than the bevel down treatments ($F_{3,36} = 0.0939$, p= 0.9629). Further comparison of treatment means in the heavy soil type suggested a difference of 167 kg ha^{-1} (149 lb ac^{-1}) or \$74 ha^{-1} (\$30 ac^{-1}) for the large shim treatment versus the bevel down geometry ($F_{3,36} = 0.0939$, p=0.9629). Increased aggression blade geometries also resulted in the highest recovered yields for the low level of late leaf spot control ($F_{3,35} = 0.2917$, p=0.8311, Table 2.5). Mean recovered yields for the three increased aggression treatments were on average 89 kg ha^{-1} (79 lb ac^{-1}) higher than those for the bevel down treatment and as large as 177 kg ha^{-1} (158 lb ac^{-1}) or \$78 ha^{-1} (\$32 ac^{-1}) higher for the large shim treatments ($F_{3,35} = 0.2917$, p= 0.8311). In the high level of late leaf spot control treatments and light soil types, increased blade aggression had no significant effects on recovered yield and trends between increased aggression and yield were not apparent (Table 2.6). Although, discussions of "trends" in this section were not of statistical significance, when considering a conservative peanut value of \$441 Mg^{-1} (\$400 ton^{-1}), the differences suggest marketable values in excess of 7.9% of the 2019 average peanut revenue per hectare in the Unites States (USDA-ERS, 2020).

Table 2.4. Mean recovered peanut dry yield (kg ha^{-1}) as a function of blade geometry across levels of late leaf spot control in heavy and light soils.

		Heavy Soil Type $F_{3,36}$ = 0.0939, p= 0.9629			Light Soil Type $F_{3,36}$ = 0.0907, p= 0.9647			
Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping [a]	SE (kg ha^{-1})
Bevel Down	10	2876	A	296.4	10	3245	A	238.4
Bevel Up	10	2852	A	296.4	10	3183	A	238.4
Small Shim	10	2894	A	296.4	10	3164	A	238.4
Large Shim	10	3043	A	296.4	10	3304	A	238.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 2.5. Mean recovered peanut dry yield (kg ha^{-1}) as a function of blade geometry across soil types in low and high levels of late leaf spot control.

		Low Level of Late Leaf Spot control $F_{3,35}$ = 0.2917, p= 0.8311			High Level of Late Leaf Spot Control $F_{3,36}$ = 0.0793, p= 0.9708			
Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping [a]	SE (kg ha^{-1})
Bevel Down	10	2399	A	156.7	10	3723	A	173.9
Bevel Up	9	2490	A	165.2	10	3685	A	173.9
Small Shim	10	2399	A	156.7	10	3659	A	173.9
Large Shim	10	2575	A	156.7	10	3772	A	173.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 2.6. Mean recovered peanut dry yield (kg ha^{-1}) as a function of blade geometry for high level of late leaf spot control in heavy and light soils.

		Heavy Soil type $F_{3,16}$ = 0.2454, p= 0.8634			Light Soil Type $F_{3,16}$ = 0.2053, p= 0.8912			
Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping [a]	SE (kg ha^{-1})
Bevel Down	5	3695	A	207.7	5	3750	A	297.4
Bevel Up	5	3833	A	207.7	5	3537	A	297.4
Small Shim	5	3581	A	207.7	5	3737	A	297.4
Large Shim	5	3683	A	207.7	5	3860	A	297.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Although not the principal factors of discussion in this paper, it is worth noting that overall level of late leaf spot control and soil type, independently, were found to significantly impact recovered yields. These findings are in agreement with previous findings in peanut production research (Anco et al. 2020; Colvin et al., 2018; Grichar et al., 1998; Kirk et al, 2014; Warner et al., 2015). Means comparison of recovered yield as a function of level of late leaf spot control across blade aggressions and soil types showed significance at α=0.05 (Table 2.7). A comparison of mean recovered yield as a function of soil type across blade aggressions and levels of late leaf spot control indicated significance at the α=0.10 level (Table 2.8).

Table 2.7. Mean recovered peanut dry yield (kg ha^{-1}) as a function of level of late leaf spot control. ($F_{1,78}$ = 117.9605, p <0.0001)

Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Low Level	40	2431	B	83.3
High Level	40	3709	A	83.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 2.8. Mean recovered peanut dry yield (kg ha^{-1}) as a function of soil type. ($F_{1,78}$ = 2.8214, p= 0.097)

Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping α=0.05 [a] (α=0.10) [b]	SE (kg ha^{-1})
Heavy Soil Type	40	2916	A (B)	129.6
Light Soil Type	40	3224	A (A)	129.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

It should be noted that the use of automated depth control on the relationship between blade geometry and recovered yield is not known as no comparisons in this study were made to compare the performance of blade geometry with and without the use of an automated depth control system. The automated depth control system acts to counteract the tendency of the digger to dive beyond favorable and prescribed blade depths. In the absence of depth control, changes in blade aggression would need to be counteracted by the operator to maintain proper depth, for example changing hitch position or top link length. The automated depth control system provided ability for the blade geometry interactions with recovered yield to be directly related to blade geometry and not substantially affected by maintenance of proper depth. Maintenance of consistent depth allowed the effects of blade - soil interactions (such as resultant soil failure, lift forces, etc.) to be identified in the absence of substantial digging depth-related effects on recovered yield, which have been found to be significant in this study and others (Warner et al., 2015).

Blade Depth

While blade depth control was automated, the control system allows depth to move within an operator-specified tolerance of a target blade depth without initiating control. Target depth was set to 58% and depth tolerance was set to ±4%. During digger setup in the field, this depth was found to be the optimal setting where tap roots were cleanly severed about an inch below the pods. Blade depth was logged throughout digging operations of each plot for the four blade geometry treatments. The resultant data is presented as the percentage of allowable depth gauge travel (blade depth percentage), with higher values indicating deeper depths and lower values indicating shallower depths. The average blade depth percentage ranged from 56.7% to 58.4% for the four blade geometry treatments.

The overall effect of blade geometry on blade depth percentage was found to be statistically significant at the α=0.05 level (Table 2.9). All blade geometries with increased aggression were found to have (significantly) deeper average blade depths than the blade bevel down treatment. Mean blade depths of the increased aggression treatments (blade bevel up, small shim, and large shim) showed significant differences between the large and small shim. However, blade depth for the blade bevel up position was not found to be statistically different than that for both the large and small shims. When paired with the respective recovered yields (Table 2.2, $F_{3,76} = 0.143$, p= 0.9339) for the bevel up blade geometry, this geometry yielded the numerically least across soil types and levels of late leaf spot control. This may suggest that the influence of blade angle or blade aggression through shimming may play a larger role in yield effect than that of blade orientation, despite similar effects on achieved depth.

The blade bevel down treatment consistently achieved the shallowest depths. The large shim treatment achieved a significantly deeper mean blade depth of 58.3% than that for the blade bevel down treatment which achieved the shallowest mean blade depth of 56.4% (Table 2.9). Significantly deeper mean blade depths were achieved by the large shim treatment as compared to the blade bevel down treatment in both the heavy and light soil types (57.8% and 58.8%, respectively); the shallowest mean blade depths (56.5% for heavy soils and 56.3% for light soils) were demonstrated by the blade bevel down treatment (Table 2.10). Although overall the blade geometry treatments did not significantly impact recovered yields in all treatment conditions in this study, it should be recognized that the average digging depths achieved by the blade bevel down geometry were shallower than the established optimal target digging depth, discussed earlier; consequently, an increased potential for reduced peanut yield recovery and greater losses during digging operations due to blade impact with the pods may occur. Kirk et al. (2014) and Roberson (2021) suggest that it is more detrimental to dig too shallow than too deep.

The results of the mean achieved depths could be found as a useful measure to quantitatively analyze blade geometry aggression relative to one another. This measure of aggression may prove useful in industry when making recommendations related to blade geometry. Mean blade depth percentage standard deviation in Table 2.9 demonstrates a general measure of average blade depth stability across plots prescribed the various blade geometries, with higher values relating to lesser stability, or more drift within the range of automated depth control tolerance. The data suggest that blade depth stability increases with increasing blade aggression, which is discussed in more detail below.

Table 2.9. Blade depth percentage and standard deviation of blade depth percentage as functions of blade geometry.

		Blade Depth Percentage $F_{3,75} = 12.1267$, $p < 0.0001$			Standard Deviation of Blade Depth Percentage $F_{3,76} = 11.1397$, $p < 0.0001$			
Treatment	N	Mean blade depth percentage (%)	T-Test Grouping[a]	SE (%)	N	Mean blade depth percentage standard deviation (%)	T-Test Grouping[a]	SE (%)
Bevel Down	19	56.4	C	0.23	20	7.83	A	0.521
Bevel Up	20	57.9	AB	0.23	20	4.17	B	0.521
Small Shim	20	57.6	B	0.23	20	4.36	B	0.521
Large Shim	20	58.3	A	0.23	20	3.48	B	0.521

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 2.10. Blade depth percentage as a function of blade geometry in heavy and light soil.

		Heavy Soil type $F_{3,36}=4.8498$, $p=0.0062$			Light Soil Type $F_{3,35} = 10.4837$, $p < 0.0001$			
Treatment	N	Mean blade depth percentage (%)	T-Test Grouping[a]	SE (%)	N	Mean blade depth percentage (%)	T-Test Grouping[a]	SE (%)
Bevel Down	10	56.3	B	0.30	9	56.5	B	0.31
Bevel Up	10	57.6	A	0.30	10	58.2	A	0.29
Small Shim	10	57.0	AB	0.30	10	58.2	A	0.29
Large Shim	10	57.8	A	0.30	10	58.8	A	0.29

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Standard deviation of blade depth percentage across the dug plots provided a measure of variability, or for use in this study, a measure of blade depth stability. Testing indicated that soil types played a significant role in blade depth and stability with lesser depths and greater stabilities in heavy soils as compared to light soils (Table 2.11). Blade geometry significantly impacted blade stability overall with mean standard deviations of blade depth percentage ranging from 3.48% to 7.83% ($F_{3,76}= 11.1397$, $p < 0.0001$, Table 2.9). Blade geometries with increased aggression demonstrated greater blade depth stability as compared to the blade bevel down geometry, with 3.47 to 4.35 percentage points lower mean standard deviation of blade depth percentage than that of the blade bevel down geometry. The blade bevel down geometry resulted in the highest standard deviation (most unstable; highest degree of variability) in all cases (α=0.05) indicating it to be the least depth-stable geometry. The large shim treatment was found to yield the lowest average standard deviation of blade depth percentage, indicating this treatment as the most depth-stable (Table 2.9). Blade depth stability was improved for each blade geometry in the heavy soil types compared to the light soil types (Table 2.12), an inherent increase in blade stability in the heavy soil type is likely due to the structure and attributes of the soil. Across the test, the increased aggression blade geometries (bevel up, small shim, and large shim) were not found to be significantly different from one another indicating little improvement in stability between the three increased aggression treatments (Tables 2.9 and 2.12). It is hypothesized that increased blade stability could provide substantial performance increases in the absence of an automated depth control system. Increased stability could offer easier control and maintenance of digger depth in a given soil type.

Table 2.11. Blade depth percentage and standard deviation of blade depth percentage as functions of soil type.

		Blade Depth Percentage $F_{1,77}$= 10.1246, p= 0.0021			Standard Deviation of Blade Depth Percentage $F_{1,78}$= 8.609, p= 0.0044			
Treatment	N	Mean blade depth percentage (%)	T-Test Grouping[a]	SE (%)	N	Mean blade depth percentage standard deviation (%)	T-Test Grouping[a]	SE (%)
Heavy Soil Type	40	57.1	B	0.18	40	4.34	B	0.442
Light Soil Type	39	58.0	A	0.18	40	5.58	A	0.442

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 2.12. Standard deviation of blade depth percentage as a function of blade geometry in heavy and light soil.

		Heavy Soil Type $F_{3,36}$= 5.0044, p= 0.0053			Light Soil Type $F_{3,36}$= 6.7458, p= 0.001			
Treatment	N	Mean blade depth percentage standard deviation (%)	T-Test Grouping[a]	SE (%)	N	Mean blade depth percentage standard deviation (%)	T-Test Grouping[a]	SE (%)
Bevel Down	10	6.65	A	0.753	10	9.00	A	0.685
Bevel Up	10	3.66	B	0.753	10	4.67	B	0.685
Small Shim	10	3.99	B	0.753	10	4.73	B	0.685
Large Shim	10	3.04	B	0.753	10	3.91	B	0.685

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Conclusion

This study demonstrates the effects of blade geometry on recovered yield and losses during the peanut digging process. The understanding gained provides a quantification of losses associated with harvest conditions while helping to improve recommendations for digger setup and operation. Findings from this study can potentially provide producers with a substantial and a sometimes significant advantage while digging peanuts. While this study cannot account for all variability across growing seasons, machinery condition and operation, and variables specific to unique harvest situations, the data presented is believed to describe effects that could vary in magnitude but consistently occur in most harvest situations.

Effects of blade geometry on recovered yield and blade depth were investigated in a variety of digging conditions. The investigation tested four blade geometries through the implementation of different blade bevel orientations (bevel up and down) and the practice of shimming blades (large and small shims). Tests were conducted across two levels of late leaf spot control and across two soil types.

It can be concluded that blade aggression plays a significant role in the recovery of peanut yield under certain harvest conditions. The study provided support that blade geometries with increased aggression positively affect recovered yield during the peanut digging process. Overall trends within the datasets point to the positive impact of increased blade aggression on recovered yields in all harvest conditions tested. In all harvest situations tested in this study, a blade geometry with increased aggression yielded the highest mean recovered yield. Mean recovered yields were generally numerically higher for the large shim geometry over the less aggressive geometries across the comparisons. Blade geometry was found to have significant ($\alpha=0.10$) impact on recovered yield in heavy soil conditions and under low leaf spot control treatments, or conceivably the most adverse digging conditions in the study. In these conditions the large shim treatment provided yield benefits of 532 kg ha^{-1} (475 lb ac^{-1}) when compared to the worst performing blade geometry for the conditions (blade bevel up). Assuming a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}), the yield benefits could provide substantial impacts of \$235 ha^{-1} (\$95 ac^{-1}) in increased revenue through the use of proper blade geometry. Further, when compared to the industry-recommended blade bevel down geometry, the large shim geometry increased mean recovered yields by 347 kg ha^{-1} (310 lb ac^{-1}), equating to increased value of \$153 ha^{-1} (\$62 ac^{-1}).

Other practical benefits of increased aggression blade geometries based on the trends and findings of this study warrant further investigation to determine significance in a wider range of conditions. However, it is believed that a positive relationship was generally evident between blade aggression and recovered yield, despite levels of statistical evidence provided in the data. A hypothesis is introduced here that increasing aggression through the use of shims improves recovered yields by providing greater lifting forces, achieving better destruction of the soil structure around the plant, thereby reducing the force required to separate the plant (and attached pods) from the soil. It is believed that the increased ability for the blade to destroy the soil structure and provide lift to the plant material is related to the general trend in increased yields seen in this study, and directly evident under the heavy soil and low leaf spot control treatment conditions. In heavy soils, soil failure occurs under a larger application of force. Additionally, disease pressure reduces peg strength, thereby reducing the required force to detach the pod from the plant when being pulled from the ground (Chapin et al., 2005); considering this, increased soil destruction and increased lift would be beneficial in instances of disease pressure. Further studies are needed to better understand the impact of blade geometry on recovered yield and effects on blade depth control in absence of an automated depth control digger. The impact of blade geometry on recovered yield may have been influenced by the specific harvest conditions present in the test, potentially affecting the magnitude of effects observed as functions of blade geometry. Therefore, more research is needed.

The study also investigated the effects of blade geometry with respect to blade depth. The study confirmed that commonly practiced methods of increasing blade aggression resulted in significantly deeper depths than the traditional factory geometry of blade bevel down. The study suggests that shimming has a greater impact on depth than changing blade orientation from blade bevel down to blade bevel up. For the two soil types included in this study the blade bevel down geometry resulted in significantly shallower digging depths (56.3% in heavy soils and 56.5% in light soils), and the large shim resulted in the deepest digging depths of 57.8 and 58.8 percent in the heavy and light soils, respectively. The target depth was set to 58% for this study, but shallower digging depths (lower percentages) are believed to increase the probability of blade impacting the peanut pod. The importance of maintenance of proper digging depth has been well documented (Kirk et al., 2014; Warner et al., 2014b). The ability of the large shims to reach and maintain depth stability at a target depth is significant in the mitigation of digging related losses.

To determine the influence of blade geometry on blade depth stability, or the variation in operating depth, the standard deviation of blade depth for each blade geometry was compared. Testing concluded that in both heavy and light soil types blade depth stability significantly increased with increased aggression. Overall, the large shim geometry was determined the most depth-stable configuration, achieving the lowest mean standard deviation in both soil types. In heavy soils, the mean blade depth standard deviation was 3.04 percent; in light soils the mean blade depth standard deviation was 3.91 percent for the large shim geometry. In comparison, the blade bevel down geometry achieved significantly higher mean blade depth percentage standard deviations of 6.65 and 9.00 percent in the heavy and light soils respectively. All methods of increased aggression were found to effectively reduce blade depth variation significantly from the bevel down geometry (Tables 2.9 and 2.12). Conceivably, reduced blade depth variability would allow operators to maintain target digging depths with better accuracy even in the absence of automated depth control capabilities, effectively reducing the potential for yield loss caused by deviation from optimal digging depths.

Further investigation is needed to determine the direct relationships between blade depth stability and yield. Although positive relationships between yield and increased aggression were concluded, and significant increases in blade depth stability due to increased blade aggression, an analysis of yield as a function of blade depth stability was not conducted. It is believed that the benefits of increased blade stability include a positive relationship with yield, reduced blade wear, and improved operator control; evaluation of these effects should be conducted in future studies in the absence of an automated depth control digger.

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CHAPTER THREE:

EFFECTS OF PEANUT DIGGER INVERSION ASSEMBLY ON YIELD AND LOSSES

Introduction

During the peanut digging process, the inversion assembly is the final system which peanuts encounter on the digger. The inversion assembly is responsible for inverting and windrowing (merging two peanut rows into a single windrow) for drying and subsequent combining of the peanut plant. The system uses a set of inversion rotors, commonly referred to as starwheels, to accelerate the peanuts onto a bank of rods. The starwheels and the bank of static, factory-set rods invert the peanut plants, resulting in the rotation of the plant and eventual inversion upon discharge from the digger (Amadas, 2011; KMC, 2014). The bank of rods used in the inversion assembly are commonly referred to as the inversion rods. Together, the starwheels and inversion rods make up the inversion assembly as it will be referred to hereafter.

The inversion assembly has not been updated since 1971 (Paulk 1971). As a feature of this design, the speed of rotation of the starwheels is directly proportional to that of the conveyor (Amadas, 2011; KMC, 2014). In other words, speed increases or decreases at the conveyor system will proportionally increase rotational speed of the starwheels. During operation, the starwheels impact the peanut plant, pods, and roots directly from the bottom of the plant (fruiting growth side), while rotating at high rpms, resulting in acceleration of the plant onto the inversion rods. Bend and position of inversion rods are set from the factory; however, maintenance of position must be performed periodically for proper inversion to result in uniform, well-structured windrows (Amadas, 2011; Bader, 2012; KMC, 2014). Aforementioned research, discussed in Chapter One: Introduction, indicated the benefits of inversion in peanut harvest, such as improved crop drying, reduced harvest losses, and windrow uniformity (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968). In 1968, Whitney et al. reported harvest losses as a function of inversion to be as low as 1.13% of recovered yield for inverting diggers versus 3.69% of recovered yield for non-inverting diggers.

Studies conducted to date have largely compared the overall performance of the inverted windrowing process to performance of alternate windrowing methods, through the comparison of various digger designs under similar harvest conditions (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968). The availability of recent research on the inversion assembly is limited. Quantification of harvest losses during the inversion process as a function of various harvest conditions and operation methods has been discussed briefly in literature. Beam et al. (2002) found that excessive vine growth reduces the efficiency of digging and inverting and increased percent pod loss. In a 2008 study, Jordan et al. indicated vegetative growth or vine load was influential in peanut inversion efficiency, and through the reduction of vine load, improved inversion efficiencies and reduced harvest losses could be achieved. Additionally, factors such as disease pressure have been investigated. Lamb et al. (2004) reported diseases were a limiting factor in recovered yield due to losses incurred at harvest. When inverting peanuts, peg strength is critical; peg strength has been noted to decrease with disease pressure and over-maturity (Chapin et al., 2005; Colvin et al., 2018; Grichar et al., 1998;

Thomas et al.,1983; Troeger et al., 1976). These studies have investigated treatments outside of the constraints of the digger. To date, no studies were found in the literature that evaluated the direct impact of the current digger inversion assembly on harvest losses in various harvest conditions. Such research is needed to quantify the related harvest impact caused by the inversion assembly.

Evidence demonstrated in the 50 plus years of study surrounding the digger/shaker/inverter point to the positive impacts on yield recovery in peanut production through the investigation of digging loss and will eventually lead to improvements in digger design. These studies have widely focused on the general interaction of the digger with various harvest conditions or operations. Absence of research evaluating the interaction of a specific component of the digger and losses indicates an area where improvement can be made. Losses associated with digging operations directly impact recovered yield and some fraction of these losses can be attributed to specific components of the digger in various harvest conditions.

Research was conducted in this study to quantify the contribution of the inversion assembly to yield loss in various digging conditions. The objectives of the study were to investigate and quantify the effect of the current digger/shaker/ inverter's inversion assembly on recovered yield and above ground losses (total and mechanical) in a range of harvest conditions. The various conditions included implementation of various conveyor speed settings, vine reduction methods with the use of the chemical growth regulator Apogee (prohexadione calcium), ground speed treatments, and various levels of disease incidence with three levels of late leaf spot control.

Materials and Methods

During the 2019 and 2020 peanut crop years, tests were conducted at Clemson University's Edisto Research and Education Center to determine the effect of the current digger/shaker/inverter inversion assembly on peanut yield recovery in various harvest conditions. The objectives of the study were to investigate and quantify the effect of the current digger/shaker/inverter's inversion assembly on recovered yield and above ground losses (total and mechanical) in a range of harvest conditions. The study described here will be referred to hereafter as the disassembly test. Harvest conditions included the implementation of various conveyor speed settings (70% to 115% conveyor speed), vine reduction through the use of chemical growth regulator (Apogee; prohexadione calcium; BASF Corp., Durham, N.C.), ground speed treatments (2.4 kph [1.5 mph], 4.0 kph [2.5 mph], 5.6 kph [3.5 mph]), and various levels of disease incidence using three levels of late leaf spot control (high, medium and low levels late leaf spot control). The primary factor of interest for the disassembly tests consisted of two digger assembly treatments: the inversion assembly installed, and the inversion assembly removed. Both the 2019 and 2020 test investigated the influence of the inversion rotors on recovered yield and above ground losses. Due to the experimental design, the use of different fields, and potential variability introduced from two crop years, direct comparison of results between the 2019 and 2020 disassembly test were not made; values in these two studies were not compared between years. However, reoccurring trends are discussed from both years. Herein after, the disassembly tests are independently referenced as the 2019 disassembly test and the 2020 disassembly test with independently defined experimental attributes and factors.

2019 Disassembly Test

For the 2019 test year, a randomized block split-split plot design with seven replications was used where the main factor was vine load treatment (Apogee or untreated check), the split factor was conveyor speed (70%, 85%, 100% or 115% of ground speed), and the split-split factor was the disassembly treatment (inversion assembly installed or removed). The field used for this study was G3A, located at the Clemson University's Edisto Research and Education Center in Barnwell County, South Carolina. A non-irrigated, conventionally tilled area of approximately 0.22 ha (0.53 ac) was utilized. The soil texture was predominantly Barnwell loamy sand (Soil Survey Staff, 2021). Peanut of a runner type variety, FloRun 331, were planted in late May of 2019 on 97 cm (38 in.) row spacing and managed utilizing Clemson University Extension guidelines. For plots prescribed the Apogee vine load treatment, two applications of 105 g a.i. ha^{-1} (1.5 oz a.i. ac^{-1}) were applied after the canopy visually reached fifty percent laterals touching during the growing season; these application rates represent three quarters of the labeled rate. The test was planted in eight row blocks alternating with four row borders, which were used as traffic passes throughout the season and excluded from the test (Figure 3.1).

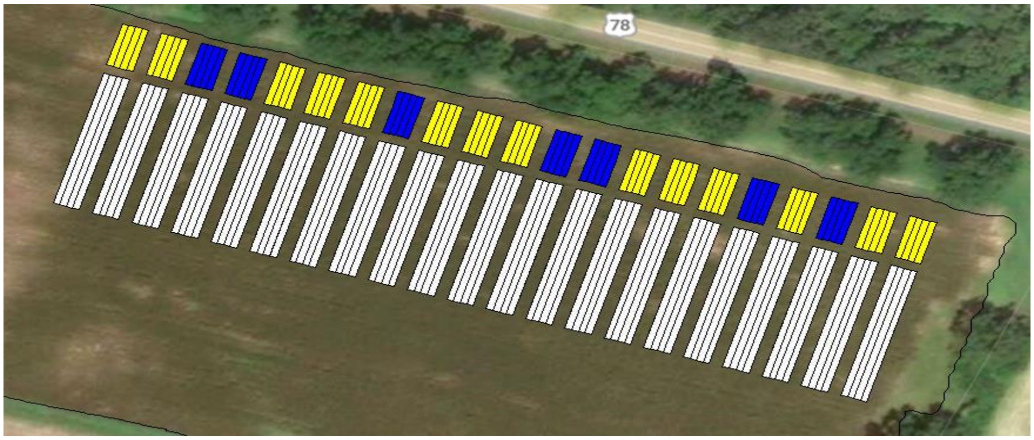

Figure 3.1. 2019 Disassembly test, showing relative positions of the Apogee treated plots (blue) and untreated check vine treatment plots (yellow) in field G3A.

The 2-row test plots were 13 m (42 ft) long with 97 cm (38 in.) row spacing. All plots were dug at an engine speed of 2,000 rpm in the same gear range, resulting in a consistent ground speed of 3.2 kph (2 mph). Peanuts were dug on October 28th, utilizing guidance lines which were assigned from planting. Conveyor speed was set based on the randomized conveyor speed treatment assigned to the plot, which was 70%, 85%, 100% or 115% of the 3.2 kph (2 mph) ground speed. Conveyor speeds were set following procedures and calculations outlined in Kirk et al. (2014). The 70% and 100% conveyor speed treatments were assigned to 28 test plots, four plots within each replication. The 85% and 115% treatments were each assigned to 14 test plots, two plots within each replication. After planting, vine control treatments of Apogee or untreated check treatments were randomly assigned to a replication. A replication consisted of three sets of eight row blocks. Each disassembly treatment was assigned to 42 test plots, two plots of which were within each eight row blocks. Conveyor speed treatment plans are shown in Figure 3.2. Plots dug under the inversion assembly removed treatment were carefully inverted by hand to insure comparable drying conditions as those inverted by the inversion assembly and in efforts to reduce any variables introduced by different drying conditions. The peanut rows were oriented in a southwest to northeast direction; consistent driving direction (northeast to southwest) was maintained during digging of each plot.

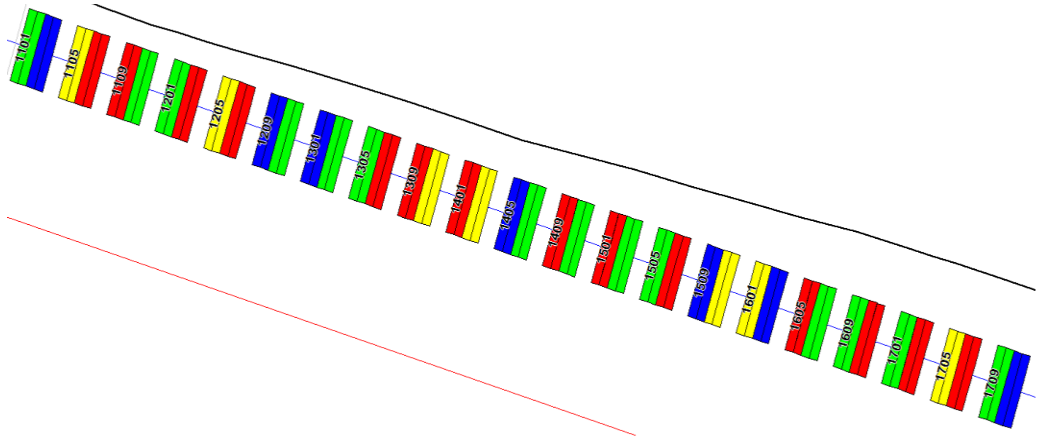

Figure 3.2. 2019 disassembly conveyor speed treatment plan for field G3A. Conveyor speed treatment assignment of 115% conveyor speed treatments (blue), 100% conveyor speed treatments (green), 85% conveyor speed treatments (yellow), and 70% conveyor speed treatments (red) are displayed.

Above ground digging losses were collected along transects bisecting each plot prior to harvesting. At the intersection of each transect and the plot's two-row windrow, above ground losses were collected by hand in a 1.2 m (4 ft) by two row area (1.9m [6.3ft]). Within this area the windrow was rolled back with care on top of itself to expose the ground below. A 1.2 m (4 ft) long by 1.9 m (6.3 ft) wide plastic frame was placed over the center of the two rows and constrained the sampling area. Above ground digging losses were defined as any pod that could be seen without disturbance of the soil; these pods were collected, and windrows were replaced (unrolled) to their original position.

Above ground digging loss samples were oven dried using a modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure; modification was necessary due to the reduced heating capabilities of available dryers. Above ground losses are reported in this study as dry weights.

Recovered yield data was collected for each plot using a 2-row Hobbs combine adapted for research plots. Harvest was conducted on November 8, 2019, 12 days after digging. The time period between digging and harvest can be attributed to the drying of the windrows due to rainfall and low ambient temperatures during this time. Combine operations were completed for the entire test in a single day and all plots were subject to the same drying conditions. Consistent machine settings were used for all plots during combining operations. The 2-row plot combine was equipped with a weighing basket which allowed for measurement of plot recovered yield weight (Kirk et al., 2012). A sample of approximately 2 kg (2 lb) was collected from each plot after recovered yield weight was recorded for moisture content analysis. These recovered yield moisture content samples were oven dried using the modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure and used for calculation of dry basis yields. Recovered yields reported herein are dry weights.

2020 Disassembly Test

Similar to the 2019 test year, a randomized block split plot design was used with five replications where factors consisted of three levels of late leaf spot control treatments (high, medium, and low) and three ground speed treatments (2.4 kph [1.5 mph], 4.0 kph [2.5 mph], 5.6 kph [3.5 mph]). The split-plot factor was the disassembly treatment (inversion assembly installed or removed). The field used for this study, D3BC, is located at the Clemson University's Edisto Research and Education Center in Barnwell County, South Carolina. D3BC was non-irrigated and managed under conventional tillage practices. Approximately 0.8 ha (2.0 ac) of the field was used for the test area. The field area is predominantly Barnwell loamy sand soils (91% sand content); in northeastern corner of the field, the soil type can be described as Wagram Sand (95% sand content) (Soil Survey Staff., 2021). A Virginia type peanut variety, Emery, was planted on in early June of 2020 on 97 cm (38 in.) row spacing and managed utilizing Clemson University Extension guidelines. The test was planted in eight test rows alternating with four border rows, which were used as traffic passes throughout the season and excluded from the test (Figure 3.3). For late leaf spot control treatment levels a fungicide application schedule was defined at planting (Table 3.1). All plots were sprayed at 60 and 90 days after planting (DAP) with 2.3 L ha^{-1} (2 pt ac^{-1}) of Convoy for white mold control, which was not investigated as a variable in this study.

Figure 3.3. Disassembly test plots, showing relative positions of the experimental plots (yellow) in field D3BC.

Table 3.1. 2020 Disassembly test fungicide application schedule.

Late Leaf Spot Control Treatment	30 DAP[a]	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP
Low Level	None	Bravo	Convoy[c]	Bravo	Bravo + Convoy	None	None
Medium Level	Bravo[b]	Bravo	Bravo + Convoy	Bravo	Bravo + Convoy	None	None
High Level	Bravo	Bravo	Bravo + Convoy	Bravo	Bravo + Convoy	Bravo	Bravo

[a] DAP- Days after planting.

[b] Bravo- Chlorothalonil(479 g ai L^{-1} [4.0 lb ai gal^{-1}]) applied at 1.8 L ha^{-1} (1.5 pt. ac^{-1}) (Syngenta Crop Protection, LLC, Greensboro, NC.)

[c] Convoy- Flutolanil (431.4 g ai L^{-1} [3.6 lb ai gal^{-1}]) applied at 2.3 L ha^{-1} (2.0 pt. ac^{-1}) (Nichino America, Inc., Wilmington, DE.)

The 2-row test plots were 20 m (65 ft) long with 97 cm (38 in.) row spacing. Peanuts were dug on November 9, 2020 or 160 days after planting. All plots were dug at a consistent engine speed in the same gear range respective to each ground speed treatment which resulted in relatively consistent ground speeds of 2.4 kph (1.5 mph), 4.0 kph (2.5 mph), or 5.6 kph (3.5 mph). Conveyor speed was set to match 100% of the ground speed treatment for each plot. Late leaf spot control treatment levels of low, medium, or high were randomly assigned to groups of two adjacent plots. At each Bravo application, 1.8 L ha^{-1} (1.5 pt ac^{-1}) of product was applied to plots, as prescribed in Table 3.1. Plots dug under the inversion assembly removed treatment were carefully inverted by hand to insure comparable drying conditions to those inverted by the inversion assembly, similarly to 2019 (Figure 3.4). Factorial combinations of the aforementioned treatments resulted in 18 unique treatments in total (three late leaf spot control levels × three ground speeds × two disassembly treatments). The peanut rows were oriented in a southwest to northeast direction; consistent driving direction (northeast to southwest) was maintained for digging of each plot.


(a) (b)

Figure 3.4. Windrowed peanuts dug with the inversion assembly installed (a) and with the inversion assembly removed (b).

Prior to combining, above ground digging losses were collected in each plot. The above ground losses for the two-row test plots were collected by hand in a 2.4 m (8.0 ft) by two-row area. Within this area, the windrow was carefully rolled back on top of itself to expose the ground below and replaced after pod collection. Digging loss collection methodology was the same as discussed for the 2019 test year, except the sample area was double that of the 2019 test year (2.4m by 1.9m [8.0 ft by 6.3ft]). Once above ground losses were collected, pods were separated into two categories: over mature and/or diseased losses (OMD) and mechanical losses. Over mature and diseased pods were defined as pods which still had a segment of the peg attached or broken along the length of the peg or those that had visible signs of over maturity, such as pink or purple discoloration of the pod. Mechanical losses were defined as those that had visible tearing of the peg from the pod; the presence of a "star" at the peg attachment point typically indicated a mechanical loss (Chapin et al., 2005). Classification of over mature and diseased losses versus a mechanical loss was maintained through rating all samples by the same individuals. All above ground samples were oven dried using the modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure. All categories of above ground loss were reported as dry weights.

Recovered yield data was collected for each plot using a 2-row Hobbs research plot combine. Harvest was conducted on December 3, 2020 in the late afternoon until dew fall and resumed after the dew had lifted on December 4th, 24 - 25 days after digging. The time period between digging and harvest can be attributed to the slowed drying of the windrows due to rainfall and low ambient temperatures during this time. All plots within a replication were exposed to consistent drying conditions and harvested on the same date. Consistent machine settings were used for all plots during combining operations. The 2-row plot combine was equipped with a weighing basket, which was used for measurement of recovered yield weight for each plot (Kirk et al. 2012). Multiple composite samples of approximately 2 kg (2 lb) were collected from the combine weighing basket on December 3-4, 2020 for determination of an average moisture content. Yield moisture content samples were oven dried using the modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure. The average wet basis moisture content was determined and used to calculate dry yield for each plot. Recovered yields reported herein are dry weights. Average moisture content was thought to sufficiently describe the moisture content of the peanuts harvested and adequate for correction of wet yields to dry yields.

Digging Operations

In both test years, digging operations utilized a Case Maxxum 140 with Trimble RTK Autopilot^{TM} (Trimble Navigation Limited, Sunnyvale, Cal.). A two-row automated depth controlled KMC 2-38 peanut digger (Kelley Manufacturing Co., Tifton, Ga.). All plots were planted and dug with the use of the Trimble RTK Autopilot^{TM} system (Trimble Navigation Limited, Sunnyvale, Cal.).

Statistical analysis

Statistical analysis was conducted using one-way ANOVA and Student's t-test (α= 0.05). Statistical analysis was performed in JMP pro v.14.1.0 statistical software (SAS Institute Inc., Cary, North Carolina). Analyses were subject to the following procedures: data sets were checked to be from a normal distribution using the Shapiro-Wilk w-test for goodness of fit (α= 0.05). If rejected for normalcy, transformations were performed utilizing a box-cox transformation (Ott et al., 2010). This was omitted if data was from a normal distribution. Once data sets were normalized, an outlier analysis was performed; outliers were excluded from the analysis on a basis following Tukey's 1.5 inter quartile range rule (Ott et al., 2010). One-way ANOVA and Students t-test were performed upon completion of the listed procedures.

Statistical analysis for the 2019 and 2020 test years, included the investigation of the overall influence of disassembly (encompassing all respective investigated factors) to compare the effects of disassembly on recovered yield, and above ground losses. Analyses of the influence of inversion assembly include interactions with conveyor speed and vine load factors for the 2019 test year and interaction of ground speed and late leaf spot control in the 2020 test year.

Results and Discussion

Yield Recovery

Recovered yield losses were quantified and associated with the inversion assembly. Both test years allowed for comparison between digging operations with the inversion assembly installed and removed. Average recovered yield for the 2019 test year ranged from 2,874 kg ha^{-1} (2,564 lb ac^{-1}) to 3,017 kg ha^{-1} (2,692 lb ac^{-1}) for the two disassembly treatments and from 2,999 kg ha^{-1} (2,676 lb ac^{-1}) to 3,096 kg ha^{-1} (2,762 lb ac^{-1}) for the 2020 test year. A large degree of variability in recovered yield was present. The overall effects of disassembly on yield recovery were not found to be significant in either year (encompassing all treatment factors).

When analyzed by vine control treatment, differences in yield recovery as a function of disassembly were not significant in the 2019 test year, but the inversion assembly installed treatment tended to result in higher mean recovered yields (Table 3.2). The summary provided in Table 3.3 indicates no significant differences in recovered yield across vine load treatments; however, mean recovered yields were numerically lower for the inversion assembly removed treatments. No significant differences were seen in recovered yield as a function of disassembly as conveyor speed increased, seen in Table 3.4. At the 115% conveyor speed treatment, the inversion assembly resulted in a lower mean recovered yield difference of 127 kg ha^{-1} (113 lb ac^{-1}) equating to a value of \$56 ha^{-1} (\$23 ac^{-1}) when compared to inversion assembly removed treatments

(Table 3.4). Despite the lack of significance, the trends of decreased average recovered yields, align with Kirk et al. (2014) findings where high conveyor speed settings (120%) resulted in higher digging losses and suggest that the inversion assembly substantially contributes to losses incurred at higher conveyor speeds. It is hypothesized that the speed at which the starwheels spin, which is dependent on conveyor speed as designed, is influential on recovered yield.

Table 3.2. Mean recovered peanut dry yield (kg ha^{-1}) as a function of disassembly for each vine load treatment in the 2019 test year.

	Untreated Check Vine Treatment $F_{1,52}$ = 0.1691, p= 0.6826				Apogee Vine Treatment $F_{1,24}$ = 0.1158, p= 0.7366			
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	27	2893	A	188.6	14	2896	A	350.6
Removed	27	2778	A	188.6	12	2721	A	378.7

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.3. Mean recovered peanut dry yield (kg ha^{-1}) as a function of disassembly in the 2019 test year. ($F_{1,74}$ = 0.3095, p= 0.5797)

Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	39	3017	A	155.5
Removed	37	2874	A	159.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.4. Mean recovered peanut dry yield (kg ha^{-1}) as a function of disassembly for the four conveyor speeds in the 2019 test year.

	70% Conveyor Speed Treatment $F_{1,25} = 0.3252$, p= 0.5736			85% Conveyor Speed Treatment $F_{1,12} = 0.076$, p= 0.7875		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	13	2852A	319.4	7	2789A	379.2
Removed	14	2589A	331.5	7	2641A	379.2
	100% Conveyor Speed Treatment $F_{1,24} = 0.1002$, p= 0.7543			115% Conveyor Speed Treatment $F_{1,11} = 0.0493$, p= 0.8283		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	14	2950A	300.8	6	2985A	417.9
Removed	12	2810A	324.9	7	3112A	386.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The 2020 test year did not demonstrate significant differences between overall disassembly treatments and recovered yield. Although the overall yield effects of the disassembly treatments in the 2020 test year were not found to be significant, comparisons of means displayed lower average recovered yields for the inversion assembly installed treatments. Inversion assembly removed treatments averaged 3096 kg ha^{-1} (2762 lb ac^{-1}) and the inversion assembly installed treatments averaged 2999 kg ha^{-1} (2676 lb ac^{-1}) across the entire study (Table 3.5, $F_{1,87} = 0.1801$, p= 0.6724). When ground speed treatment factors were considered, the data failed to demonstrate statistically significant differences in recovered yield, but recovered yields were numerically higher for the inversion assembly removed treatments than the inversion assembly installed treatments at all tested ground speeds. Comparing mean recovered yields, the inversion assembly installed treatments resulted in lower recovered yield by 106 kg ha^{-1} (95 lb ac^{-1}) at the 2.4 kph (1.5 mph) ground speed ($F_{1,28} = 0.0656$, p= 0.7998), 81 kg ha^{-1} (72 lb ac^{-1}) at the 4.0 kph (2.5 mph) ground speed ($F_{1,27} = 0.0482$, p= 0.8279), and 105 kg ha^{-1} (94 lb ac^{-1}) at the 5.6 kph (3.5 mph) ground speed ($F_{1,28} = 0.0659$, p= 0.7992) (Table 3.6). Across all ground speed treatments, removal of the inversion assembly increased yield recovery by an average of 97 kg ha^{-1} (87 lb ac^{-1}), a peanut value of \$43 ha^{-1} (\$17 ac^{-1}). While recovered yield was not found to be statistically different across assembly treatments for the three ground speeds tested, removal of the inversion assembly resulted in consistent numerical increases in mean recovered yields. While not compared here, the general reduction of mean recovered yield at increasing ground speeds agrees with the findings of Kirk et al. (2017), that increased speed is negatively related to recovered yield. However, the contribution of inversion assembly to this negative relationship is not evident in the findings here.

Table 3.5. Recovered yield (kg ha^{-1}) as a function of disassembly in the 2020 test year. ($F_{1,87}$ = 0.1801, p= 0.6724)

Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	44	2999	A	161.2
Removed	45	3096	A	159.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.6. Recovered yield (kg ha^{-1}) as a function of disassembly for the three ground speeds in the 2020 test year.

	2.4 kph Ground Speed $F_{1,28}$ =0.0656, p= 0.7998			4.0 kph Ground Speed $F_{1,27}$ =0.0482, p=0.8279			5.6 kph Ground Speed $F_{1,28}$ =0.0659, p=0.7992		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	15	3195A	294.0	14	2953A	264.7	15	2846A	287.5
Removed	15	3301A	294.0	15	3034A	255.7	15	2951A	287.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The mean recovered yields of disassembly treatments across high, medium, and low levels of late leaf spot control ranged from 2027 kg ha^{-1} (1808 lb ac^{-1}) to 3924 kg ha^{-1} (3501 lb ac^{-1}). The results indicated no significant differences in recovered yield as a function of disassembly at varying levels of late leaf spot control. Overall, the inversion assembly removed treatments resulted in an average of 42 kg ha^{-1} (38 lb ac^{-1}) higher average recovered yields across all levels of late leaf spot control, equating to increased revenue of \$19 ha^{-1} (\$8 ac^{-1}). The inversion assembly removed treatments resulted in increased yields of 131 kg ha^{-1} (117 lb ac^{-1}) or \$58 ha^{-1} (\$23 ac^{-1}) for medium late leaf spot control ($F_{1,26} = 0.2493$, p= 0.6218) and 38 kg ha^{-1} (34 lb ac^{-1}) or \$17 ha^{-1} (\$7 ac^{-1}) for low late leaf spot control ($F_{1,28}$ =0. 0232, p= 0.88) (Table 3.7). Statistical significance was not indicated despite differences in yields, but a high degree of variability was present in the dataset. The effect of disassembly treatments was also analyzed across ground speed treatments in the three levels of late leaf spot control and no statistical differences were noted (Tables 3.8-3.10). Relationships here were inconsistent, with recovered yield being higher for the inversion assembly removed treatments in five out of nine comparisons. When disassembly treatments were compared under 5.6 kph (3.5mph) ground speeds and the low late leaf spot control, noted to be the harshest harvest conditions tested, the mean recovered yield was 355 kg ha^{-1} (317 lb ac^{-1}) (\$157 ha^{-1} [\$63 ac^{-1}]) higher for the inversion assembly removed treatments (Table 20). Overall, regardless of disassembly treatment, recovered yield was found to be significantly different across the three levels of late leaf spot control (Table 3.11) and in alignment with Grichar et al. (1998) findings of reduced yields resultant of late leaf spot pressure.

Table 3.7. Recovered yield (kg ha^{-1}) as a function of disassembly for three levels of late leaf spot control in the 2020 test year.

	High Level Late Leaf Spot Control Treatment $F_{1,28} = 0.0264$, p= 0.872			Medium Level Late Leaf Spot Control Treatment $F_{1,26} = 0.2493$, p= 0.6218			Low Level Late Leaf Spot Control Treatment $F_{1,28} = 0.0232$, p= 0.88		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	15	3924A	190.5	14	3050A	184.8	15	2027A	177.7
Removed	15	3881A	190.5	14	3181A	184.8	15	2065A	177.7

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.8. Recovered yield (kg ha^{-1}) as a function of disassembly for the three ground speeds at low late leaf spot control in the 2020 test year.

	2.4 kph Ground Speed $F_{1,8} = 0.1323$, p= 0.7255			4.0 kph Ground Speed $F_{1,8} = 0.2328$, p= 0.6424			5.6 kph Ground Speed $F_{1,8} = 0.4459$, p= 0.5231		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	2223A	318.7	5	2211A	244.8	5	1645A	375.8
Removed	5	2150A	318.7	5	2044A	244.8	5	2000A	375.8

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.9. Recovered yield (kg ha^{-1}) as a function of disassembly for the three ground speeds at medium late leaf spot control in the 2020 test year.

	2.4 kph Ground Speed $F_{1,8} = 0.6265$, p= 0.4515			4.0 kph Ground Speed $F_{1,7} = 0.3930$, p= 0.5506			5.6 kph Ground Speed $F_{1,8} = 0.1157$, p= 0.7425		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	3282A	440.2	4	2722A	333.3	5	3082A	342.8
Removed	5	3775A	440.2	5	3002A	298.1	5	3247A	342.8

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.10. Recovered yield (kg ha^{-1}) as a function of disassembly for the three ground speeds at high late leaf spot control in the 2020 test year.

	2.4 kph Ground Speed $F_{1,8} = 0.0347$, p= 0.8568			4.0 kph Ground Speed $F_{1,8} = 0.1757$, p= 0.6861			5.6 kph Ground Speed $F_{1,8} = 0.1668$, p= 0.6937		
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	4080A	380.4	5	3881A	298.8	5	3812A	357.7
Removed	5	3979A	380.4	5	4057A	298.8	5	3606A	357.7

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.11. Recovered yield (kg ha^{-1}) as a function of late leaf spot control in the 2020 test year. ($F_{2,86}$= 48.2584, p <0.0001)

Late Leaf Spot Control Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Low Level	30	2046	C	134.9
Medium Level	29	3201	B	137.2
High Level	30	3902	A	134.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The recovered yield values indicated here are believed to be influenced by the confounding variable of manual inversion of the peanut plants by the research team; thus, the importance of proper inversion is believed to be reflected in the 2019 and 2020 disassembly yield data. This explanatory statement is presented here in consideration of research conducted by Whitney et al. (1968) and Bader (2012) where random inversion and poor windrow structure is suggested to reduce recovered yield.

Total Above Ground Losses

The impact of disassembly on above ground digging losses was also analyzed for the 2019 and 2020 test years. Total above ground losses ranged from 81 kg ha^{-1} (72 lb ac^{-1}) to 94 kg ha^{-1} (84 lb ac^{-1}) for the 2019 year and averaged 827 kg ha^{-1} (738 lb ac^{-1}) to 844 kg ha^{-1} (753 lb ac^{-1}) for the 2020 test year.

The overall effect of the inversion assembly on above ground losses was not found to be significant during the 2019 test year ($F_{1,82}$ = 2.1645, p= 0.1451). However, average above ground losses were higher by 13 kg ha^{-1} (12 lb ac^{-1}) for the inversion assembly installed treatments (Table 3.12). In no instances for the 2019 test year were above ground losses statistically different for the disassembly treatments. Further, in instances of vine load control treatments, Apogee vine load treatments as a function of disassembly demonstrated average above ground loss of 14 kg ha^{-1} (13 lb ac^{-1}) higher for inversion assembly installed versus inversion assembly removed ($F_{1,26} = 0.6051$, $p = 0.4436$) (Table 3.13). Average above ground losses for the inversion assembly installed treatment were 11 kg ha^{-1} (10 lb ac^{-1}) greater than those for the inversion assembly removed treatment under the untreated check vine load treatments ($F_{1,54} = 1.6799$, $p = 0.2004$) (Table 3.13). Comparisons of digging loss means were performed across the four conveyor speeds tested. Although not significant, these generally suggested an increasing influence of the inversion assembly on above ground losses when the conveyor was set to speeds faster or slower than 100% conveyor speed and increased with deviation from 100% conveyor speed (Table 3.14) which is in alignment with the findings presented in Kirk et al. (2017). At 100% conveyor speed ($F_{1,26} = 0.0267$, $p = 0.8714$), the lowest difference between mean above ground losses for the two inversion assembly treatments was observed. The greatest difference observed at the 115% conveyor speed setting ($F_{1,12} = 2.9287$, $p = 0.1127$) where mean above ground losses for the inversion assembly installed treatment was 26 kg ha^{-1} (23 lb ac^{-1}) greater than that for the inversion assembly removed treatment.

Table 3.12. Total above ground losses (kg ha^{-1}) as a function of disassembly in the 2019 test year. ($F_{1,82} = 2.1645$, $p = 0.1451$)

Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	42	94	A	5.9
Removed	42	81	A	5.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.13. Total above ground losses (kg ha^{-1}) as a function of disassembly in methods of vine load treatment in the 2019 test year.

	Untreated Check Vine Treatment $F_{1,54}$ = 1.6799, p= 0.2004				Apogee Vine Treatment $F_{1,26}$ =0.6051, p= 0.4436			
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	28	89	A	6.2	14	102	A	12.5
Removed	28	78	A	6.2	14	88	A	12.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.14. Total above ground losses (kg ha^{-1}) as a function of disassembly under varying conveyor speeds in the 2019 test year.

	70% Conveyor Speed Treatment $F_{1,26}$ = 1.0548, p= 0.3139			85% Conveyor Speed Treatment $F_{1,12}$ = 0.2051, p= 0.6587		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	14	96A	11.6	7	93A	11.2
Removed	14	79A	11.6	7	86A	11.2
	100% Conveyor Speed Treatment $F_{1,26}$ = 0.0267, p= 0.8714			115% Conveyor Speed Treatment $F_{1,12}$ = 2.9287, p= 0.1127		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	14	87A	11.2	7	101A	11.0
Removed	14	85A	11.2	7	75A	11.0

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The 2020 test year did not demonstrate any significant differences between the overall effect of the disassembly treatments on above ground losses ($F_{1,84} = 0.965$, p= 0.7568). Average above ground losses contradicted the trends found in the 2019 testing, and the inversion assembly installed treatments overall achieved lower mean above ground losses (Table 3.15). The magnitude of total above ground losses was 8.8 times greater in the 2020 test year than the 2019 test year. The influence of field maturity levels, varying disease presence and extended time between digging and above ground loss collection were all believed to attribute to the scale of these losses. Above ground losses for this study were 27.4% of the field average recovered yield. Therefore, to better understand the effects of disassembly treatments, mechanical losses will be discussed later in this chapter. When above ground losses were analyzed for the disassembly treatments with respect to ground speeds, the inversion assembly installed treatments demonstrated mean above ground losses of 9 kg ha^{-1} (8 lb ac^{-1}) and 6 kg ha^{-1} (5 lb ac^{-1}) larger than those for the inversion assembly removed treatments at 2.4 kph (1.5 mph) ($F_{1,26}$= 0.0064, p= 0.937) and 5.6 kph (3.5mph) ($F_{1,24}$ = 0.0061, p= 0.9385), respectively. At the 4.0 kph (2.5 mph) speed treatment, the mean above ground losses for the inversion assembly installed treatments was numerically lower than that for the inversion assembly removed treatment (Table 3.16); while not significant at the α=0.05 level, the differences at this ground speed were substantially greater than at the other two ground speeds.

Table 3.15. Total aboveground total losses (kg ha^{-1}) as a function of disassembly in the 2020 test year. ($F_{1,84}$ = 0.965, p= 0.7568)

Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	45	827	A	37.4
Removed	41	844	A	39.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.16. Total aboveground losses (kg ha^{-1}) as a function of disassembly for varying ground speeds in the 2020 test year.

	2.4 kph Ground Speed $F_{1,26}$ = 0.0064, p= 0.937			4.0 kph Ground Speed $F_{1,27}$ = 2.2865, p= 0.1421			5.6 kph Ground Speed $F_{1,24}$ = 0.0061, p= 0.9385		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	15	809A	75.2	15	805A	53.2	13	872A	56.3
Removed	13	800A	80.8	14	906A	55.1	13	866A	56.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Above Ground Mechanical Losses

Above ground losses collected in the 2020 test year were categorized into losses apparently caused by mechanical influence or effects of over maturity and disease, as defined earlier. Testing did not indicate significant differences between the overall effect of the disassembly treatments on mechanical above ground losses ($F_{1,86} = 1.6231$, $p = 0.2061$). The mechanical above ground losses are summarized in Table 3.17 across both disassembly treatments and ranged from 52 kg ha^{-1} (46 lb ac^{-1}) to 62 kg ha^{-1} (55 lb ac^{-1}) for the inversion assembly installed treatment and inversion assembly removed treatment, respectively. Mean mechanical above ground losses were numerically greater for the inversion assembly installed treatment compared to the inversion assembly removed treatment.

Table 3.17. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly in the 2020 test year. ($F_{1,86} = 1.6231$, $p = 0.2061$)

Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	45	62	A	5.3
Removed	43	52	A	5.4

[a] Treatments with the same letter indicate no significant differences ($\alpha=0.05$).

Disassembly treatments were found to significantly impact mechanical losses at ground speeds of 4.0 kph (2.5 mph) (Table 3.18). A means comparison indicated an increase in mechanical above ground losses of 23 kg ha^{-1} (21 lb ac^{-1}) (Table 3.18, $F_{1,26} = 4.928$, $p = 0.0354$) for the inversion assembly installed treatment. No statistical differences were present for the disassembly treatments when tested at ground speeds of 2.4 kph (1.5 mph) and 5.6 kph (3.5 mph) in the 2020 test year.

Table 3.18. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly for the three ground speeds in the 2020 test year.

	2.4 kph Ground Speed $F_{1,26}$ = 0.509, p= 0.4819			4.0 kph Ground Speed $F_{1,26}$ = 4.928, p= 0.0354			5.6 kph Ground Speed $F_{1,28}$ = 0.0168, p= 0.8978		
Inversion Assembly Treatment	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	14	55A	6.2	14	57A	9.8	15	69A	8.9
Removed	14	50A	6.2	14	34B	9.8	15	71A	8.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Analysis of above ground mechanical losses for levels of late leaf spot control across the two disassembly treatments indicated no significant differences at the α=0.05 level (Table 3.19). A comparison of means between disassembly treatments revealed a reoccurring trend across the three levels of leaf spot control; average above ground mechanical losses were higher in the inversion assembly installed treatments for all three levels of late leaf spot control. Differences in mean mechanical losses of the disassembly treatments were found to be as large as 15 kg ha^{-1} (13 lb ac^{-1}) in the medium late leaf spot control treatments (Table 3.19, $F_{1,27}$ = 1.1483, p= 0.2934) and as small as 2 kg ha^{-1} (2 lb ac^{-1}) in the low late leaf spot control treatments (Table 3.19, $F_{1,28}$ = 0.0034, p= 0.9536).

Table 3.19. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly for the three levels of late leaf spot control in the 2020 test year.

	High Level Late Leaf Spot Control $F_{1,27}$ = 1.0222, p= 0.321			Medium Level Late Spot Control $F_{1,27}$ = 1.1483, p= 0.2934			Low Level Late Leaf Spot Control $F_{1,28}$ = 0.0034, p= 0.9536		
Inversion Assembly Treatment	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	15	70A	9.7	15	56A	9.1	15	59A	8.9
Removed	14	57A	10.1	14	41A	9.4	15	57A	8.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Differentiation of the data set into multifactorial data sets (levels of late leaf spot control by ground speed) indicated no instances of significant differences due to the disassembly treatments. The inversion assembly removed treatments generally resulted in lower mechanical above ground losses. In one instance, mean above ground mechanical losses were 44 kg ha^{-1} (39 lb ac^{-1}) greater for the inversion assembly installed treatment under the high level late leaf spot control and 4.0 kph (2.5 mph) treatment factors (Table 3.20, $F_{1,7} = 2.3201$, p= 0.1715). In all other instances, the magnitude of losses was lower. In two instances, above ground mechanical losses were found to be higher under the inversion assembly removed treatments, both instances occurred at 3.5 mph digging speed and under low (Table 3.21, $F_{1,8} = 0.0258$, p= 0.8764) and high (Table 3.20, $F_{1,8} = 0.3321$, p= 0.5803) levels of late leaf spot control. Average above ground mechanical losses were higher for the inversion assembly installed treatments in all other breakouts of late leaf spot control and ground speed. No statistical significance was found at the α=0.05 level for these analyses.

Table 3.20. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly for the three ground speeds at the high late leaf spot control level in the 2020 test year.

	2.4 kph Ground Speed $F_{1,8} = 0.6071$, p= 0.4583			4.0 kph Ground Speed $F_{1,7} = 2.3201$, p= 0.1715			5.6 kph Ground Speed $F_{1,8} = 0.3321$, p= 0.5803		
Inversion Assembly Treatment	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	53A	8.1	5	81A	24.0	5	76A	12.8
Removed	5	44A	8.1	4	37A	26.8	5	87A	12.8

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.21. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly for the three ground speeds at the low late leaf spot control level in the 2020 test year.

	2.4 kph Ground Speed $F_{1,8}=0.0857$, p= 0.7771			4.0 kph Ground Speed $F_{1,8}=0.5599$, p= 0.4757			5.6 kph Ground Speed $F_{1,8}=0.0258$, p= 0.8764		
Inversion Assembly Treatment	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	73A	19.4	5	46A	14.1	5	58A	12.5
Removed	5	71A	19.4	5	40A	14.1	5	60A	12.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Conclusion

This study demonstrates the effects of the inversion assembly on recovered yield and losses during the peanut digging process. The study was conducted in an effort to provide better understanding of the contributions of individual digger components, specifically the inversion assembly, to harvest loss generation and yield recovery, an area where minimal information is readily available. The understanding gained provides a quantification of losses associated with various harvest conditions while helping to suggest opportunities for improvements in inversion design. Conclusions from this study and their like cannot account for the impact of variability across growing seasons, machinery condition and operation, and variables specific to unique harvest situations encountered during the inversion process. However, the data presented is believed to describe effects that could vary in magnitude but consistently occur in all harvest situations.

The 2019 and 2020 test years sought to quantify peanut harvest losses associated with the inversion assembly in various harvest conditions. The effect of the inversion assembly was tested through the performance of digging operations with an automated depth controlled KMC 2-38 digger with the inversion assembly removed and installed. Multiple analyses were conducted utilizing recovered (collected) yield, total above ground losses, and mechanical above ground losses.

The experimental design sought to quantify losses and yield recovery associated with the inversion assembly installed or removed. For the inversion assembly removed treatments, windrows were manually inverted. The digging losses and recovered yield values found in this study were believed to be influenced by manual inversion. In several comparisons it was apparent that recovered yields and above ground losses were higher, for the inversion assembly installed treatment. Generally, an inverse relationship exists between recovered yield and above ground losses, increasing and decreasing simultaneously. These findings suggest that recovered yield for the inversion assembly installed treatments out-performs manual inversion, while also generally incurring greater above ground losses. It is believed that these findings preclude the studies ability to isolate and distinguish losses specifically associated with the inversion assembly. In light of these results, further assessment of the methodology may explain why losses and yields sometimes decreased simultaneously for manual inversion. When the inversion assembly was removed from the digger, the rows of vines exiting the conveyor simply fell to the ground. Normally peanut vines are propelled onto the inversion rods by the starwheels, where typically they descend with a degree of control through the inversion rod, discharging closely to the ground. As an unintentional effect of the manual inversion process, the uncontrolled fall, invariably separated individual plants within the rows from one another. Peanut plants and vines are often entangled with one another (Young et al., 1982). It was observed by the researcher in this study that peanut plants in the rows were often spaced at about 8 cm (3 in.), and pods were attached to pegs on the plant routinely as far as 15 cm (6 in.) from the taproot. Physically separating two adjacent plants' entangled vines from one another invariably results in severing pegs intertwined with the adjacent plant, resulting in pod loss. Hypothetically if separation occurred at one out of every four plants, resulting in two lost pods from the two adjacent plants, a potential magnitude of increased loss and decreased yield recovery of about 112 kg ha^{-1} (100 lb ac^{-1}) could occur for the inversion assembly removed treatment. It is also thought that additional losses due to plant separation would also have been incurred from the inversion assembly removed treatment (in relative excess of the inversion assembly installed treatment) when plants feed into the combine header. While this inadvertent effect of the methodology resulted in a general inability to isolate yield and loss effects specifically associated with the inversion assembly, the findings of this study are still useful in better understanding digging losses associated with inversion for improvement of digger design and digging recommendations. In fact, this realization in and of itself, that separation of adjacent plants in rows can result in increased pod losses and could lead to future improved recommendations and designs.

While inadvertent, additional losses were likely imposed by virtue of manual inversion in the inversion assembly removed treatments, any losses of the inversion assembly installed treatments in excess of those for the inversion assembly removed treatments can still be associated with the inversion assembly. Although, this would only represent a subset of losses associated with the inversion assembly. The study concluded that above ground mechanical losses are significantly increased due to the effects of the inversion assembly in some harvest situations and that the performance of the current design of the inversion assembly is optimized within a narrow range of machine and crop parameters. Operation outside of these ranges can result in significant detriments during digging and inversion of the peanut crop. By defining the inversion assembly's limits and quantifying losses, improvements to the peanut digging processes may be made. By maintaining operation within the limitations of the digger's individual components, machine efficiencies can be maximized. The following conclusions were drawn from the findings of the studies.

Significant increases of losses due to the inversion assembly were found. In the 2020 test year, above ground mechanical losses were found to increase by 23 kg ha^{-1} (21 lb ac^{-1}) when the inversion assembly was installed, and peanuts were dug at 4.0 kph (2.5 mph) (Table 3.18). These findings suggest that growers may incur significantly increased losses due to the inversion assembly, even at ground speeds found to be in an optimal digging ground speed range discussed by Kirk et al. (2017). Further, proper conveyor speed settings, proper ground speed and the maintenance of vine load through reduction of vegetative growth in conjunction were effective means to reduce losses caused by the inversion assembly seen in this study.

Further support is discussed here. The mean recovered yields from the 2019 test year generally indicated lower mean yield recovery when the inversion assembly was installed in instances of heavy vine loads. Recovered yields were reported up to 127 kg ha^{-1} (113 lb ac^{-1}) lower when the inversion assembly was installed at conveyor speed treatments of 115%. Further, for the 115% conveyor speed treatments, mean above ground losses were highest numerically across all conveyor speed treatments for the inversion assembly installed treatments, as compared to those for the inversion assembly removed treatments. The mean above ground losses at the 115% conveyor speed were found to be 26 kg ha^{-1} (23 lb ac^{-1}) greater for the inversion assembly installed treatments than those for the inversion assembly removed treatments ($p>0.05$). In addition to the recognized trends discussed earlier, mean above ground losses generally increased for the inversion assembly installed treatments as conveyor speeds diverged from the 100% conveyor speed treatment, suggesting the optimal operational range of the conveyor speed for the conditions in the test; conveyor speed is directly proportional to rotational speed. Generally, deviation from 100% conveyor speeds (higher or lower) resulted in larger differences in recovered yield, increasing in magnitude with deviation of conveyor speed from 100%. In the 2019 test year conveyor speed treatments allowed for simulated effects at heavy vine loads; increased conveyor speeds resulted in increased starwheel rotational speeds in excess of resultant vine speeds, due to the retardance of vine flow from heavy vine loads. Additional methods to investigate the influence of vine loads in this study were through the use of a chemical growth regulator (Apogee, prohexadione calcium) for vine load reduction. In contrast to conveyor speed treatments, which simulate differential velocities between vines and starwheels caused by heavy vine loads, chemical vine load control results in a decrease in vine mass on the plant, effectively reducing vine load. In the absence of statistical significance, a general increase in mean recovered yields were found for the Apogee treatments when compared to the untreated check treatments overall (87 kg ha^{-1}, 78 lb ac^{-1}). In general, Apogee vine load treatments as a function of disassembly experienced a range of average above ground loss from 88 kg ha^{-1} (79 lb ac^{-1}) to 102 kg ha^{-1} (91 lb ac^{-1}), which were 14 kg ha^{-1} (13 lb ac^{-1}) higher for the inversion assembly installed versus the inversion assembly removed treatments. Under untreated check vine load conditions, 11 kg ha^{-1} (10 lb ac^{-1}) higher average above ground losses were determined for the inversion assembly installed versus the inversion assembly removed treatments. The 2019 test year indicated the potential for increased average above ground losses attributed to the inversion assembly, these losses exceeded those from the inversion assembly removed treatment by 27 kg ha^{-1} (24 lb ac^{-1}) in heavy vine conditions. In the 2020 test year, testing was conducted at varying ground speeds; across these treatments, the average recovered yield was higher for the inversion assembly removed treatments across all three ground speeds tested. The inversion assembly removed treatment at 2.4 kph (1.5mph) ground speed resulted in the highest mean recovered yield, 3,301 kg ha^{-1} (2,945 lb ac^{-1}). At 2.4 kph (1.5 mph), the inversion assembly removed treatments demonstrated a 106 kg ha^{-1} (95 lb ac^{-1}) greater mean recovered yield over the inversion assembly installed treatments. Inherently, when ground speed is increased the feed rate of peanut material is increased, effectively increasing vine load per unit time. Considering this, at the 5.6 kph (3.5 mph) ground speed treatment the vine loading rate would be highest among those tested; at this speed, the lowest numerical recovered yield means were obtained across ground speed treatments. At 5.6 kph (3.5 mph) recovered yield for the inversion assembly installed treatment was 105 kg ha^{-1} (94 lb ac^{-1}) lower than that for the inversion assembly removed treatment. Further, under varying ground speed treatments, the inversion assembly installed treatment as earlier discussed was found to cause significantly ($p<0.05$) more mechanical above ground losses than the inversion assembly removed treatments, suggesting a 23 kg ha^{-1} (21 lb ac^{-1}) reduction in mechanical losses at 4.0 kph (2.5 mph). Again, support for a range of optimized performance of the inversion assembly was realized. The magnitude of mean mechanical losses was minimized at the 4.0 kph (2.5 mph) speed treatments in all leaf spot control levels when the inversion assembly was removed. The 2020 test year showed the potential for inversion assembly to create significant losses even at optimal conditions. The results generally indicated an increase in losses with the increase of speed. The inversion assembly installed treatments averaged 97 kg ha^{-1} (87 lb ac^{-1}) lower recovered yields as compared to those for the inversion assembly removed treatments across the three speeds; larger scale studies may indicate a significant negative relationship between the inversion assembly and recovered yield as a function of ground speed or may be likely to better reveal the relationship between the inversion assembly and vine load. Furthermore, as discussed, yield and loss differences presented here likely attribute less yield and loss effect to the inversion assembly than that for which they are actually responsible. Since its comparator in this study, the inversion assembly removed treatment, was inherently likely to induce substantial losses due to vine separation.

Overall, the inversion assembly removed treatments resulted in 42 kg ha^{-1} (37 lb ac^{-1}) higher average recovered yields across all levels of late leaf spot control ($p>0.05$). Additionally, mean above ground mechanical losses under the three varying levels of leaf spot control resulted in numerically higher losses for the inversion assembly installed treatments across all levels of disease pressure. Further, the inversion assembly was found to negatively affect recovered yield in the presence of high levels of disease pressure and increased ground speeds. The study showed that the inversion assembly negatively impacted crop recovery, mean recovered yield differences of 355 kg ha^{-1} (317 lb ac^{-1}) were found where the inversion assembly was installed and peanuts were dug under low levels of leaf spot control and high ground speeds (5.6 kph, 3.5 mph) ($p>0.05$). Assuming a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}) and the aforementioned 355 kg ha^{-1} (317 lb ac^{-1}) recovered yield loss, revenue detriments could be estimated at \$157 ha^{-1} (\$63 ac^{-1}) due to the inversion assembly under these conditions. Trends within the above ground mechanical losses in respect to ground speed under the three levels of late leaf spot control displayed a consistent trend of higher mean losses for the inversion assembly installed as compared to the inversion assembly removed treatments. These findings suggest that when suboptimal harvest conditions are present the inversion assembly becomes more impactful. The importance of disease control and proper digging speeds should be emphasized to reduce the negative impact caused by the inversion assembly.

As discussed earlier in this section, the recovered yield and measured loss data for the inversion assembly removed treatments relied on the plants falling to the ground from the end of the conveyor and on the researcher to manually inverting the plants. Both of these processes had the effect of separating adjacent, intertwined plants, which is believed to have influenced recovered yields and measured losses in both years of testing to a large degree. The importance of properly inverted, well-structured windrows is reiterated here. Recovered yield overall was not found to be statistically different between the disassembly treatments for either year of testing. It is worthwhile to consider the lack of significant differences and likelihood of losses induced from plant separation for the inversion assembly removed treatment; the lack of significant differences in losses and yield between the disassembly treatments is believed to be indicative that when inversion properly occurs under optimal digging conditions, the mechanism of inversion may not be significantly impactful to the recovery of yield. Thus, when suboptimal digging conditions are present, the recovery of yield is likely directly related to the performance limitations of the mechanism. Therefore, optimization of recovered yield in peanut harvest is currently constrained by the performance parameter limits of the inversion mechanism. Although in some harvest situations investigated an increase in yield losses was associated with the inversion assembly, its current use is beneficial compared to removing the inversion assembly in the absence of alternative inversion methods and leaving vines non-inverted.

The results discussed in this study point to the opportunity for improvements in the current inversion assembly on modern peanut diggers. Within optimal operational conditions the modern digger’s performance minimizes peanut digging losses. However, the potential for conditions to deviate from these constraints affecting performance in a harvest situation can be significant. The amount of variability encountered during peanut harvest is vast. To better determine the effects of the inversion assembly on the inversion process, research is needed in a wide range of harvest conditions. Additionally, research is needed in comparison to alternate methods of inversion, other than manual inversion, to better isolate specific effects of the current inversion assembly. Currently, the starwheel and inversion rod assembly is the most widely used and available inversion assembly on peanut diggers in the United States. Therefore, improvements to the design and better understanding of the inversion methods offer the potential for substantial positive impacts in the peanut industry.

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CHAPTER FOUR:

EFFECTS OF VINE LOAD ON DIGGING AND STRATEGIES TO ADDRESS VINE LOAD

Introduction

Peanut (*Arachis hypogaea* L.) production and harvest can be described as unique due to the peanut's anatomy; this offers many challenges during the crop's production cycle. The anatomy of the peanut plant requires that peanuts be harvested in a two-step process beginning with digging. Overall the harvest process has been noted as a major source of yield losses, with a high magnitude of losses incurred during the digging or inversion process under a multitude of variables including crop health, maturity, disease, weed pressure, digger setup, digger condition, digging ground speed, steering precision, and environmental and soil conditions (Bader et al., 2012; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; Roberson et al., 2014; Warner et al., 2015; Wright et al., 1991; Young et al., 1982). Decisions made throughout the growth cycle of the peanut are abundantly important for accumulation of yield as well. These management decisions can directly impact subsequent decisions made at harvest, which are crucial to the recovery of marketable yield from the crop. Management of vine growth is one variable peanut producers are faced with combating throughout the season and during the digging process. During the peanut production cycle, the accumulation of vine growth is often excessive to that needed for maximum yield accumulation (Mitchem et al., 1996). Excessive vine growth can result in harvest inefficiencies, including difficulties navigating rows during digging, reduced digger and inversion efficiency, increased mechanical damage, and increased harvest losses (Culpepper et al., 1997; Beam et al., 2002; Jordan et al., 2008; Mitchem et al., 1996; Roberson et al., 2014). To mitigate the effects of increased vine loads during digging caused by excessive vegetative growth, literature suggests operators reduce ground speed (Amadas, 2011; Kirk et al., 2017; KMC, 2014; Roberson, 2021). Although effective, the associated increased labor and operation costs, reduction in field capacity and risk of crop loss due to slowed digging makes the investigation of alternate methods of contending with increased vine load valuable. Investigation of proactive methods of vine control and alternate digger setups, to allow for maintenance of economically advantageous ground speeds while effectively mitigating harvest deficiencies caused by heavy vine conditions would likely be of significant interest and impact during digging.

Vine Mass Control

The mitigation of vine load ideally occurs prior to the peanut digging and inversion process, during the growing season, preventing producers from needing to face the challenges of heavy vine loads at harvest. Conceivably, control of peanut vine mass prior to digging allows for a more uniform peanut crop to be dug and harvested. Vine mass control can be achieved through means of mechanical and chemical vine mass reduction.

Mechanical vine mass reduction can be achieved by mowing the vine canopy prior to digging. A 1969 study examined the interaction between an early prototype digger, mowing half of the peanut canopy, and drying efficiency of the peanut crop (Person et al., 1969). The prototype digger used was reported to have difficulty inverting rows and its use was discontinued after the first year of study (Person et al., 1969). Little yield effect was reported to have occurred as a result of the mowed vine treatments, likely due to the digger used in the 1969 study. The relationship of the mowed treatment and current peanut diggers has only been revisited in limited capacities in reported research, despite advancements in peanut diggers and cultivars. However, since the 1969 study the direct investigation of the relationship of mowing the peanut canopy and the effects on digging has not been a primary factor of investigation in any of the documented studies found. However, in the early 1980s Young et al. (1982) reported that the mowing of vines was a common pre-digging operation to reduce vine load and aid in the efficiency of pod separation from the vine during combining. Young et al. (1982) further warned that the excessive mowing of vines should be avoided due to the poor handling of short plants within the digger, suggesting removal of no more than the top one-third of the canopy prior to digging; however, supporting research was not presented with this claim and likely derived from observation. More recently, Monfort (2021) reported that the resurgence of runner type peanut cultivars with vigorous vegetative growth have resulted in peanut producers mowing the top one-third of the peanut canopy to combat excessive vine growth in efforts to reduce harvest losses incurred at digging. Further, related studies have researched the application of mowing vines as a principal factor in use for disease management and an alternate revenue source through the sale of the canopy as animal forage. In the late 1990s, Butzler et al. (1998) indicated mowing to be beneficial to the recovery of yield when heavy disease pressure and excessive vine growth was present. Additionally, Sorenson et al. (2009) reported that in-season forage harvest did not dramatically reduce recovered peanut yield when the peanut canopy was mowed to a height of 20 cm (8 in.) 120 days after planting and clippings were collected shortly before digging operations for its sale as animal forage (9 to 32 days prior to digging). More notably, the study reported yield from mowing to be not significantly different compared to that following application of prohexadione calcium plant growth regulator (Sorenson et al., 2009); this study suggested that yield effects of vine mass reduction through mechanical and chemical means may be similar.

Since the 1970s, peanut producers have been utilizing plant growth regulators in peanut production to manage vine growth and promote harvest efficiency (Beam et al., 2002; Culpepper et al., 1997; Gorbet et al., 1990; Mitchem et al., 1996; Monfort et al., 2021; Studstill et al., 2021). In the 1980s the plant growth regulator prohexadione calcium, which is widely used today, was discovered; prohexadione calcium is an acylcyclohexandione growth regulator which reduces internode length by blocking biosynthesis of gibberellins responsible for cell elongation (Culpepper et al., 1997; Mitchem et al., 1996; Motojima et al., 1984). Benefits of prohexadione calcium's reduction of vegetative growth have been indicated in numerous studies since its introduction. Reported benefits include increased row visibility, improved digging efficiency, and reduction in disease pressure (Beam et al., 2002; Culpepper et al., 1997; Faircloth et al., 2006; Jordan et al., 2008; Studstill et al., 2021). In 2002, Beam et al. (2002) reported treatments of prohexadione calcium applied at 50% row closure and re-applied two weeks later increased recovered yield by 220 kg ha^{-1} (196 lb ac^{-1}) and reduced pod loss by four percent. Beam et al. (2002) suggested the increased recovered yield was a function of pod retention or the reduction of pod losses, hypothesizing it was due to a treated plant holding on to pods more tightly than an untreated plant. Further, a multi-year, multi-state investigation concluded that yield benefits of 453-731 kg ha^{-1} (404-652 lb ac^{-1}) across large on-farm trails were significant due to the application of prohexadione calcium at reduced label rates, although significant yield effects were not reported inform corresponding small plot experiments (Studstill et al., 2021). The study by Studstill et al. (2021) examined reduced rate prohexadione calcium applications of one-half and three-quarter labeled rates; two applications of both reduced rates were found to provide similar growth inhibition as the two seasonal applications of full label rate of 140 g a.i. ha^{-1} (2 oz a.i. ac^{-1}) when conducted on both small and large on-farm plot experiments. In addition to the various studies and aforementioned yield benefits, Monfort et al. (2021) reiterated yield improvements when prohexadione calcium was applied at three-quarter label (105 g a.i. ha^{-1}; 1.5 oz a.i. ac^{-1}) rates to runner market-type peanuts but found that the cost of application surpassed the increase in revenue associated with yield improvements and would reduce profitability. The previously mentioned studies suggest that vine mass reduction through application prohexadione calcium is effective and beneficial in peanut production. However, the identification of the interaction between the crop production system, specifically the digging processes, and effects of vine mass reduction through the application of prohexadione calcium is not defined through research in current literature.

Mechanical Vine Load Control

Despite efforts to mitigate vine load at harvest, producers may often still be faced with situations where heavy vine growth has occurred in regions or the entirety of a field where excessive growth is promoted by favorable conditions. In these situations, producers seeking to reduce losses could conceivably rely on machinery adjustments during digging operations. Digger optimization for given field conditions has been previously investigated, resulting in significant harvest benefits with understanding of current conditions and proper digger settings. However, little information is available on digger setting optimization with respect to vine load.

Further, during digging operations, losses have been documented to occur throughout the digging process if digger performance is not optimal for the conditions present at harvest (Amadas, 2011; Kirk et al., 2017; Peanut Grower, 2017; Warner et al., 2014a; Zerbato et al., 2017).Various studies suggest potential losses during harvest are influenced by factors including crop condition, digger setup and condition, steering precision, and environmental conditions (Bader, 2012; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; Roberson et al., 2014; Warner et al., 2015; Wright et al., 1991; Young et al., 1982). Further, as previously discussed, vine conditions such as excessive vine growth result in reduced digger and inversion efficiency, reduced row navigation (steering) accuracy, increased mechanical damage, and increased harvest losses, thus indicating a direct relationship between vine load and peanut digger operation (Beam et al., 2002; Culpepper et al., 1997; Jordan et al., 2008; Roberson et al., 2014; Mitchem et al., 1996). In efforts to optimize efficiency of digging operations Young et al. (1982)

proposed that timing of digging should be a function of maturity in conjunction with field and vine conditions. Therefore, it can be hypothesized that optimization of adjustable digger settings, such as conveyor speed and inversion rod spacing, for the present vine growth is an effective way to reduce harvest detriments.

Limited research is available on the effects of varying digger conveyor speed settings. In general, industry recommendations for conveyor speed settings are predominately limited to very few sources, presumably reliant on observations and experience. Amadas industries (Suffolk, Va.) and Kelly Manufacturing Co. (KMC, Tifton. Ga.) suggest matched conveyor speeds and ground speeds. Bader (2012), however, suggests conveyor speed should be set slightly faster than forward speed to avoid the accumulation of vines prior to conveyor pickup. Subsequently, Robertson (2021) states that conveyor speed is optimal when matched to ground speed to avoid dragging and snatching of the plants or slightly faster under various given harvest conditions. None of these sources provide scientific evidence supporting their recommendations. A 2017 study, by Kirk et al. (2017) investigated the effects of conveyor speed settings under consistent vine growth management strategies; yield maximization was reported to occur at the 100% conveyor speed settings under normal vine conditions. Further, results indicated benefits of lagging conveyor speeds (70-80%) in heavy Virginia type vine loads (Kirk et al., 2017). Kirk et al. (2017) also suggested conveyor speeds excessive of 110% of ground speeds be avoided, offering the explanation that excessive conveyor speeds result in the ripping of pods from the soil. Observations presented in Chapter 3 suggest that another mechanism may also be responsible for increased losses at conveyor speeds in excess of ground speed: separation of plants from adjacent, intertwined plants resulting in dislodged pods. Conversely, it was also proposed by Kirk et al. (2017) that slowed conveyor speeds can result in increased bunching and agitation of the vines prior to conveyor pickup. An investigation of conveyor speed optimization through the integration of a newly developed peanut digger precision technology was performed in 2008 at N.C. State University, in which a digger was fitted with an automated conveyor control system that varied conveyor speed to match ground speed (Roberson, 2008). The study reported reduction of above and below ground losses with conveyor speed optimization (Roberson, 2008), providing further evidence for the benefits of conveyor speed optimization based on crop conditions.

Preliminary research of the potential vine load control strategy of rod spacing adjustments with respect to vine load, revealed only general recommendations for rod spacing performance. No previous studies were identified in a review of literature which investigated the effects of various digger inversion rod spacing on peanut harvest. Therefore, the available information on rod spacing is believed to be entirely supported by tendencies and observations made in respect to the inversion rods during the digging process, likely to be more associated with windrow structure and appearance than with measured digging losses. Inversion rods spacing is static while digging and set from the factory; the bank of rods forms a partial, imperfect helix and receives vines propelled by the inversion rotors, resulting in plant inversion upon discharge from the digger under proper operation (Amadas, 2011; KMC, 2014). Periodic maintenance is recommended to ensure proper inversion and produce uniform, well-structured windrows (Amadas, 2011;

Bader, 2012; KMC, 2014). A 2021 harvest guide suggests that inversion rods should be inspected to ensure rods are not damaged or corroded and spaced based on factory recommendations to reduce associated harvest losses (Roberson, 2021). Roberson (2021) additionally recommends that identification and elimination of potential choke points be incorporated into pre-digging machinery checks, indicating that poor vine flow performance and an increase in loss potential is resultant of improper rod positioning. Considering the manufacturer specifications and general recommendations, recommended rod spacing seemingly is determined by: (1) consistent and complete inversion and (2) observation of negative effects associated with the retardance of vines due to narrowed rod spacing. One might hypothesize that at various levels of vine load, rod spacing could be adjusted, specifically in efforts to optimize rod engagement with the plant for better inversion while minimizing impedance of vine flow.

Methods to Monitor Vine Load Control

In the United States, peanut production has often benefited from the adoption of new technologies. Evident from the shift of windrow harvesting in the 1950s, which greatly reduced the labor requirements of peanut production at the time (Wright et al., 1979) to the growth in popularity of digger/shaker/inverters in the 1970s, which provided benefits in drying performance, windrow uniformity, and reduced harvest losses over previously available diggers and harvest methods (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968). Adoption of technology in peanut production spans to today's peanut production climate, where precision agriculture technology is readily accepted and adopted, especially technologies such as Real Time Kinematic (RTK) position correction and autosteering. In general, technology adoption has benefited peanut production and agriculture as a whole, through the reduction of labor requirements, increased input efficiencies, and increases in recovered yields. Precision agriculture used on planted peanut acres in the United States was estimated in 2013 to exceed 54% (USDA-ERS, 2019), indicating the perceived benefits of its implementation in the industry. Further, supporting production benefits of the precision agriculture technology, RTK autosteering was reported in a 2020 Clemson University study which indicated that the use of RTK autosteering could provide an average estimated operator benefit of \$223 ha^{-1} (\$90 ac^{-1}) over manual steering methods (Samenko et al., 2020). Another study indicated a substantial recovered yield increase when comparing the use of RTK autosteering with manual steering during digging, quantifying the losses associated with peanut digging operations as a function of RTK guidance line deviation (Ortiz et al., 2013). In the 2013 study, a consistent row center deviation error was intentionally imposed, resulting in 118 kg ha^{-1} (105 lb ac^{-1}) of loss in recovered yield per 1.27 cm (0.5 in.) of row centerline deviation (Ortiz et al., 2013). Further, benefits of producer adoption of RTK autosteering were reported as reduced harvest losses, which were attributed to the increase in precise row navigation, reduced operator fatigue and distraction, and proper row center identification despite vine mass accumulation during digging operations (Balkcom et al., 2010; Ortiz et al., 2013; Roberson et al., 2014; Saavoss, 2018). These examples indicate the value in application of precision agriculture technology in the industry

Additional, newly developed precision agriculture technologies, although not commercially available, have been investigated in peanut production. The aforementioned study at N.C. State University where a variable speed conveyor technology was developed to adjust conveyor speed relative to ground speed via feedback provided by an adapted variable rate sprayer technology was found to reduce above and below ground losses with its implementation (Roberson, 2008). In 2014, a variable depth peanut digger was introduced by Clemson University; the technology provided automated feedback-based digging depth adjustment through the adjustment of a hydraulic top link (Warner et al., 2014a). The prototype variable depth peanut digger technology was estimated to demonstrate a reduction in yield losses, valued at \$47 ha^{-1} (\$19 ac^{-1}) (Warner et al., 2014b). Precision technologies such as the ones discussed here indicate substantial and sometimes significant value in their employment in peanut production and indicate the potential benefits of future technological advances in the industry.

The Effects of Vine Load and Strategies to Reduce Vine Load Study

In the 40 plus years of study and use of plant growth regulators in peanut production, effects are generally reported to positively reduce vine mass in peanut production (Beam et al., 2002; Culpepper et al., 1997; Faircloth et al., 2006; Gorbet et al., 1990; Jordan et al., 2008; Mitchem et al., 1996; Monfort et al., 2021; Studstill et al., 2021). However, the elevated cost incurred with the application of the plant growth regulator prohexadione calcium as compared to revenue benefits indicated by Monfort et al. (2021) provides interest in the exploration of other, more economically beneficial ways to alter or address vine load prior to or during digging. Research is needed to explore alternate methods and to document the interaction of vine load and the current peanut digger, through quantitative data analysis and scientific observation.

Further, the impact of the presented studies, which identify harvest related loss due to digger setup in peanut production, offer substantial insight into the benefits of proper digger setup and optimization for harvest conditions. One might hypothesize that optimization of digger settings as a function of vine load may provide similar benefits or mitigation of negative effects as those in the various studies and technologies discussed earlier. Despite guidance from a few known studies, many recommendations regarding digger setup in various conditions are apparently based on general observations and experience during digging. Absence of research evaluating the interaction of a specific component of the digger and vine load, through a quantification of losses reveals an area where improvement and advancements in knowledge is needed.

Harvest benefits in the reduction of losses associated with improvement of digging operations by precision agriculture technologies can impact recovered yield directly, and implementation of various precision technologies have proven beneficial. Therefore, due to the high potential of losses during digging (Bader, 2012; Kirk et al., 2014; Kirk et al., 2017; Kirk et al., 2021; Roberson et al., 2014; Warner et al., 2015; Wright et al., 1991; Young et al., 1982), the potential yield benefits following optimization of digger settings (Kirk et al.,2014; Roberson, 2008; Samenko et al., 2020), and benefits of implementation of advancing precision agriculture technologies (Balkcom et al., 2010; Ortiz et al., 2013; Roberson, 2008; Roberson et al., 2014; Saavoss, 2018; Warner et al., 2014a; Warner et al., 2014b), research that promotes the improvement of harvest efficiency relative to vine load through advancements and adaptations of precision agriculture technologies is needed.

The contributions of the previously discussed studies and many others have helped to better define the relationship between digging operations the recovery of peanut yield. While large improvement potential in the recovery of yield during digging has been realized, there remains room for improvement. A more thorough understanding of the peanut digger's interaction with the peanut crop during harvest, is needed to help producers maximize efficiencies and profitability.

Objectives

The objectives of this study were to evaluate the effects of vine load and strategies to reduce vine load on peanut digging operations. The research focused in three categories: (1) addressing mechanical and chemical vine load (mass) control methods, (2) vine load compensation through adjustment of digger settings (conveyor speeds and inversion rod spacing), and (3) methods to monitor vine load machine conditions for potential of feedback-based vine load compensation (application of speed sensing). The specific objectives were to: (1) quantify yield and digging losses as functions of three vine load control treatments designed to manipulate vine load prior to digging, (2) quantify yield and digging losses as functions of conveyor speed and inversion rod spacing treatments designed to compensate for vine load during digging under the three treatments defined in objective 1, and (3) evaluate the application of vine speed sensing for indicating conditions favorable to inversion related losses.

Materials and Methods

A two-year study (2018 and 2019) was conducted at Clemson University's Edisto Research and Education Center to determine the effects of vine load on peanut digging operations. The applications of the plant growth regulator Apogee (prohexadione calcium), mechanical mowing of vines, and an untreated check were used in the investigation of objective 1. Research and methods conducted as a component of objective 1 will be referred to as Vine Mass Control Strategies. The second objective was designed to evaluate compensation or response strategies for vine load during digging under the three treatments defined in objective 1. Three inversion rod spacing treatments and five conveyor speed settings relative to a ground speed of 4.0 kph (2.5 mph) were used in the 2018 test year. Four conveyor speed settings relative to a ground speed of 3.2 kph (2 mph) in the 2019 test year were investigated under objective 2. Research and methods conducted under objective 2 will be referred to as Mechanical Vine Load Compensation Strategies. Objective 3 was to evaluate the application of vine conveying velocity sensing for indicating conditions conducive to inversion related losses. A radar ground speed sensor was directed at the general area of row merging above the inversion assembly to determine if a relationship between vine speed there and vine loading rate within the digger existed during inversion. Research and methods performed under objective 3 is described using the nomenclature Methods to Monitor Vine Load Conditions. Direct comparisons were not made between the two years of the study, although, reoccurring trends can be discussed from both years. Due to the experimental design, the use of different fields, and potential variability introduced from two crop years, direct comparison of results should only be made between treatments within a growing season.

2018 Effects of Vine Load and Strategies to Address Vine Load Study

A total of 8.1 ha (20 ac) in two fields (E8A and E8B) at Clemson University's Edisto Research and Education Center in Barnwell County, South Carolina were planted in a runner type variety, FloRun 331. The two conventionally tilled, non-irrigated fields were planted in early June of 2018 on 97 cm (38 in.) row spacing and managed under Clemson University Extension guidelines. The soils of E8A and E8B are comprised of Orangeburg Loamy Sand (84% sand content), Barnwell Loamy Sand soils (91% sand content), Wagram Sand (95% sand content) and Ailey Sand (92% sand content) (Soil Survey Staff, 2021). The experimental design of the study utilized a randomized block split-split plot design with three replications. The principal factor was inverter rod spacing treatments (narrow, standard, and wide), the split factor was vine mass control treatment (Apogee, mowed, and untreated check), and the split-split plot factor consisted of a subset of five conveyor speeds depending on inverter rod spacing treatment expressed as a percentage of ground speed. Subsets specific to each inverter rod spacing are defined in the next section. Eight adjacent planted rows alternated with four row borders across the field, which were used as traffic passes throughout the season and excluded from the test (Figure 4.1a). Plots were defined as two-rows of varying length, each equal to field length (ranging from 110m [360 ft] to 274 m [900 ft] in length), with 97 cm (38 in.) row spacing. Plots in field E8A were oriented in a northwest to southeast direction and plots in field E8B were oriented in a northeast to southwest direction. Three transects (A, B, and C) were imposed on the field; above ground losses were collected and vine velocities were recorded at the intersection of these transects with the plots

(Figure 4.1b). Above ground losses were categorized as mechanical losses or over mature and diseased losses. Prior to combining, inversion ratings were measured and reported as a percentage of poorly inverted plants (methodology later defined). Digging operations were performed on October 23rd and 24th using a Case Maxxum 140 with Trimble RTK Autopilot™ (Trimble Navigation Limited, Sunnyvale, Cal.). A two-row automated depth controlled (Warner et al., 2014a) KMC 2-38 peanut digger (Kelley Manufacturing Co., Tifton, Ga.) was used in all plots while digging in combination with the Trimble RTK Autopilot™ system (Trimble Navigation Limited, Sunnyvale, Cal.). All plots were dug at consistent engine speeds and gear ranges, resulting in a ground speed of 4.0 kph (2.5 mph). Digging direction was consistent for plots in each replication.

2018 Vine Mass Control

Application of the plant growth regulator Apogee (active ingredient prohexadione calcium) (BASF Corp., Durham, N.C.), mechanical mowing of vines, and an untreated check treatment were used to quantify the effects of vine mass control strategies on digging losses and inversion. To investigate the effect of the three vine mass control strategies, each of the treatments were randomly assigned to one eight row block within each 24 row block of rod spacing treatments. Plots which were prescribed the Apogee vine mass control treatments received two applications at the three-quarter labeled rate (105 g a.i. ha^{-1}; 1.5 oz a.i. ac^{-1}). Apogee was applied after the canopy visually reached fifty percent of laterals touching during the growing season. Plots under the mowed vine mass control treatments were mowed to a height of about eight inches using a 12 ft rotary mower with the Trimble RTK Autopilot™ system. Mowing was performed on the same day as digging, directly before digging operations commenced. Check treatment plots were untreated and did not receive any method of vine mass control. Vine conditions in the vine mass treatments are shown in Figure 4.2.

(a). (b). (c).

Figure 4.2. Vine mass control treatments applied to the 2018 study showing untreated check (a), Apogee (b), and mowed (c).

2018 Mechanical Vine Load Compensation

Varying inversion rod spacing, and conveyor speed settings were used to determine the effects of mechanical compensation for vine load during digging. Three inversion rod spacing treatments were used to investigate effects of mechanical vine load control strategies on yield and digging losses. Groupings of three eight-row blocks from 2018 vine mass control treatments were randomly assigned to an inversion rod spacing treatment (narrow, normal and wide), shown in Figure 4.3. One random two-row plot from each wide rod spacing block was assigned a normal row spacing to accommodate five tested conveyor speeds in the standard rod spacing and three tested conveyor speeds in the wide rod spacing. Standard rod spacing was defined by industry recommendations for inversion rod spacing on a KMC 2-38 peanut digger (KMC, 2014). Narrow and wide inversion treatments were achieved by moving the rod tips 8 cm (3 in.) narrower or wider than the factory specified locations. A total of 27 plots were prescribed the wide treatment, 45 plots were assigned the standard treatment and 36 were tested with the narrow inversion rod treatments.

Figure 3.3. Mechanical vine load compensation strategy rod spacing treatment plan for E8A and E8B in 2018. Blue strips represent narrow rod spacing, red strips represent standard rod spacing, and yellow strips indicate wide rod spacing.

Five conveyor speed settings were set following procedures and calculations outlined in Kirk et al. (2017); conveyor speeds were expressed as a percentage of the ground speed of 4.0 kph (2.5 mph) and were randomly assigned to plots as follows. In the narrow inversion rod spacing treatment, conveyor speeds used were 65%, 76%, 100%, and 115%. In the standard inversion rod spacing treatment, conveyor speeds used were 65%, 76%, 89%, 100%, and 115%. In the wide inversion rod spacing treatment, conveyor speeds used were 89%, 100%, and 115%. The 115% and 100% conveyor speed treatments were assigned to a total 27 test plots, the 89%, 76%, and 65% conveyor speed treatments were assigned to 18 plots each.

2018 Methods to Monitor Vine Load Conditions

To evaluate the application of conveying vine speed sensing for indicating conditions favorable to inversion related losses a Dickey-john Radar II (DICKEY-john, Auburn, Ill.) radar ground sensor was adapted and installed on the KMC 2-38 peanut digger (Kelley Manufacturing Co., Tifton, Ga.). The radar was oriented so that the area of row merger above the inversion assembly would be monitored (post-conveyor off load) to determine if a relationship exists between monitored vine speed, vine load conditions within the digger, and harvest losses (Figure 4.4). Vine speed was recorded for the duration of the tests in field E8A and E8B across the 108 plots. The radar output was connected to a Phidgets 1054_0B frequency counter (Phidgets Inc., Calgary, Alberta, Canada) and logged throughout the test at a frequency of 10 Hz, along with RTK corrected GPS positions (update rate of 1 Hz). Data logging was conducted using software developed in Visual Basic 2010 using Microsoft Visual Studio Express 2010 (Microsoft Corp., Redmond, Wash.). A high-speed camera (60 frames per second) was installed to view the general area of row merger, which the radar was monitoring; videos were recorded at the intersection of plots and the three imposed transects in field E8B (Figure 4.1b). Prior to digging on the day of the test, the transect intersection lines were marked, perpendicular to the row, on the peanut canopy with orange spray paint. Video recordings began before the painted transect lines entered the digger and ended after the marked vines had exited the digger. Video recordings taken across 67 transect lines were utilized for analysis discussed later. Radar speeds assigned to each plot-transect intersection were averaged across 6.1m (20.0 ft) at the imposed transect lines, with 3.1m (10.0 ft) of the given plot length on each side of the transect.

Figure 4.4. 2018 mounting configuration of radar ground speed sensor, center of digger, and high-speed camera, to the left of the radar sensor.

2019 Effects of Vine Load and Strategies to Address Vine Load Study

The 2019 Effects of Vine Load and Strategies to Address Vine Load Study was conducted in a 1.3 ha (3.2 ac) area of a field (G3A) at Clemson University's Edisto Research and Education Center in Barnwell County, South Carolina. The conventionally tilled, non-irrigated field was planted in early May of 2019 on 96.5 cm (38 in.) row spacing with a runner type peanut, FloRun 331. The field was managed under Clemson University Extension guidelines and planted with the use of the Trimble RTK Autopilot^{TM} system previously described in a roughly southwest to northeast row orientation. The soils of the area utilized in G3A for testing were predominantly Barnwell Loamy Sand with 91% sand content (Soil Survey Staff, 2021). A randomized block split plot design was used for the study. The vine mass control treatment was the primary factor, consisting of three treatments: Apogee, mowed, and untreated check. The split factors were the four conveyor speed treatments (70%, 85%, 100% or 115%). The study consisted of seven replications, each comprised of three sets of eight row blocks and four traffic rows. Each group of eight treatment rows was alternated with four rows of border used as traffic passes throughout the season and excluded from testing. Experimental plots were two rows of 46 m (152 ft) in length with 97 cm (38 in.) row spacing. A transect line was imposed on the field intersecting the center of the plots; above ground losses were collected, and vine velocities were recorded at the intersection of this transect and each plot (Figure 4.5). As described earlier, inversion ratings were measured before combining and reported as a percentage of poorly inverted plants. Plots were dug on October 24th with a Case Maxxum 140 with Trimble RTK Autopilot™ and a two-row automated depth controlled (Warner et al., 2014a) KMC 2-38 peanut digger. Consistent driving direction with engine speed and gear ranges were maintained, resulting in a ground speed of 3.0 kph (2.0 mph) across the entire study. Recovered yield was collected using a 2-row Hobbs plot combine designed for research. The combine is equipped with a weighing system which allows for measurement of plot recovered yield weight. Due to the capacity of the weighing system, weights were recorded at the transect line and ends of plot row. Further description of the weighing system is provided by Kirk et al. (2012). In addition, a sample of approximately 2 kg (2 lb) was collected for moisture analysis from each plot after recovered yield weight was recorded. Harvest was conducted on November 8th and 9th, 12-13 days after digging. Poor drying conditions were experienced due to rainfall and ambient temperatures during the drying time. All plots within a replication were exposed to consistent drying conditions and consistent settings were used on the combine across all plots within the study. The 2kg (2lb) moisture samples were initially weighed for a moisture content analysis; samples were then oven-dried using a modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure and dry weights were recorded after drying. Modification of the S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) was necessary due to the temperature limits of the dryers used. Moisture content for each plot was used for correction of recovered yield to dry basis. Recovered yields reported herein for the 2019 Effects of Vine Load and Strategies to Address Vine Load Study are dry weights.

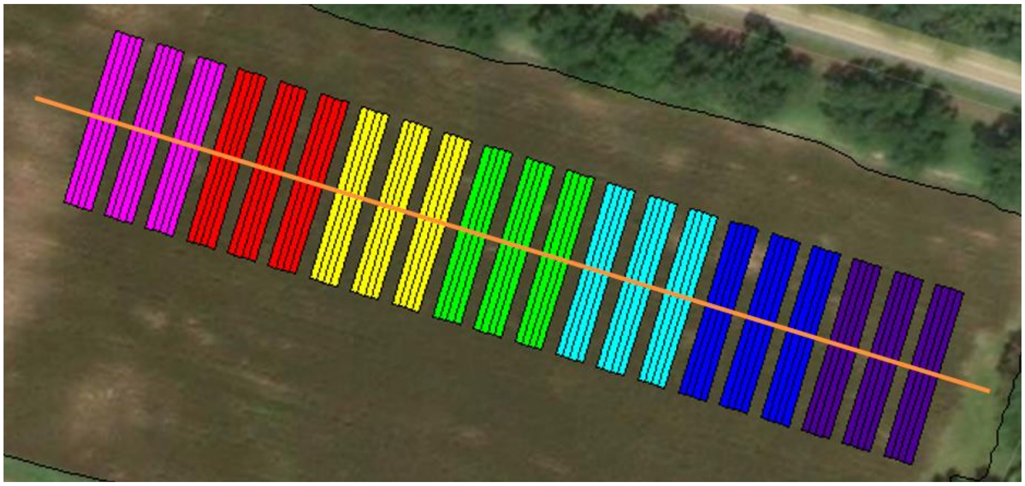


Figure 4.5. Experimental plot layout in 2019 by replication blocks. Unique colors indicate a replication of three 8-row blocks, the imposed transect location is indicated in orange.

2019 Vine Mass Control

Vine mass control strategies were assigned at random to one eight row block within each replication using the same treatments (Apogee, mowed and check) as described for 2018 testing. Within each replication, plots were randomly assigned to each of the three vine mass control treatments, in groupings of 4 plots (8 rows). The afternoon prior to digging (October 23rd), the mowed treatments were mowed to a height of 20 cm

(8 in.) with a 4 m (12 ft) rotary mower, using the Trimble RTK Autopilot™ system to ensure accuracy. Untreated check plots did not receive any method of vine mass control. Figure 4.6 illustrates the vine conditions of the crop before digging.

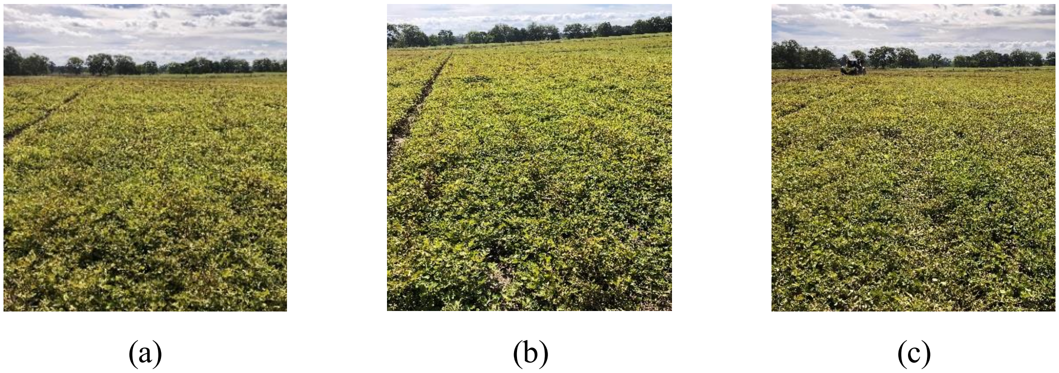


Figure 4.6. Vine mass control treatments applied to the 2019 study showing untreated check (a), Apogee (b), and mowed (c).

2019 Mechanical Vine Load Compensation

Four conveyor speed settings were used to determine the effects of mechanical compensation for vine load during digging; treatments were assigned to each of the four plots within each group of vine mass control treatment. Contrasting to 2018, no rod treatments were prescribed for this portion of the study. Inversion rods were set to the specifications defined by industry recommendations for inversion rod spacing on a KMC 2-38 peanut digger (KMC, 2014). Conveyor speed settings were relative to a ground speed of 3.2 kph (2.0 mph) at 75%, 85%, 100%, and 115%. Conveyor speed treatments were randomly assigned to 4-plot blocks prior to digging. Twenty-one plots were assigned to each of the four conveyor speed treatments. Similar to 2018 Vine Mass Control Strategies, conveyor speed treatments were employed using procedures and calculations outlined in Kirk et al. (2017).

2019 Methods to Monitor Vine Load Conditions

The Dickey-john Radar II (DICKEY-john, Auburn, Il.) radar ground sensor from 2018 Methods to Monitor Vine Load Conditions was installed on the KMC 2-38 peanut digger for digging operations. The positioning of the radar was changed from the previous year of study (2018). Preliminary testing was conducted to determine the bounds of the effective radar cone to measure speed. Steel framework was temporarily installed on the digger in the area of row merger above the inversion assembly (after conveyor offload). A coordinate system was imposed relative to the temporary framework onto a plane that was perpendicular to the estimated plane of travel for the tops of the peanut plants. A belt sander was used to simulate the linear movement of peanut plants along this coordinate plane; the belt sander's velocity was determined to be 16.9 kph (10.5 mph). Radar sensor response was recorded for a defined time in 7.6 cm (3 inch) iterations across the coordinate plane (x, y), where the origin (0, 0) represented the face of the radar sensor, x values represented distance from the sensor face along the horizon, and y values represented distance from the sensor face perpendicular to the horizon. Average velocity readings at each point were evaluated, velocities within ±50% of 16.9 kph (10.5 mph) were utilized to construct a simple model of the effective radar cone (Figure 4.7). The radar was adjusted so that the area above the inversion assembly would be optimally monitored (after conveyor off load) based on these findings (Figure 4.8a). The radar was repositioned closer (10 cm; 4 in.) to the vines and the radar mounting angle was adjusted to 35 degrees from the plane representing the tops of the peanut plants as compared to the 25-degree angle to this plane as utilized in the 2018 testing. Vine speed was measured across the entirety of each of the 84 treatment plots. Data acquisition was the same as described for 2018. High speed videos were also collected in 2019 at the intersection of the transect line with each plot (Figure 4.8b) using the same materials and methodology described for 2018. Eighty-two video recordings taken across the transect line were analyzed from 2019 to determine camera monitored vine speeds.

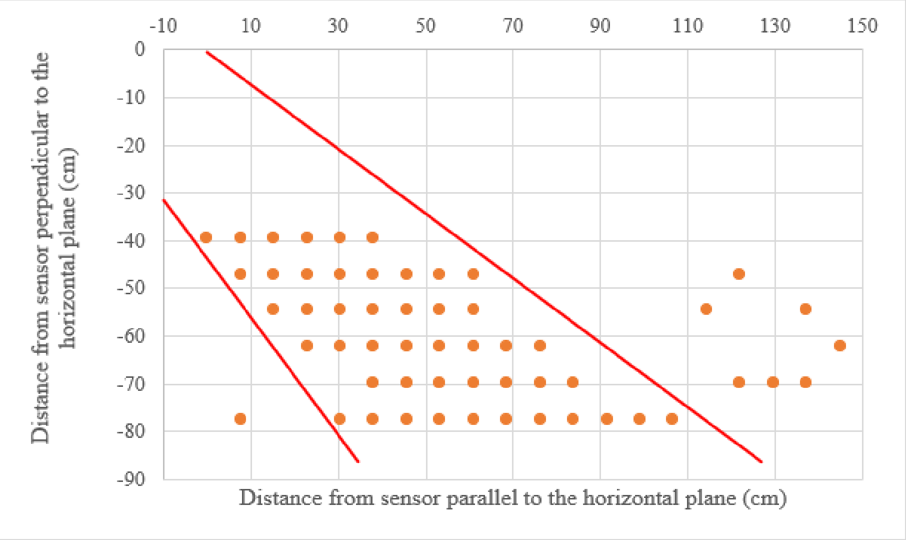


Figure 4.7. Graphical representation of the effective radar speed sensing cone from preliminary position testing in 2019. Each dot on the chart represents a belt sander (simulated linear motion) position where the radar-indicated velocity was within ±50% of the known belt sander linear velocity.

(a) (b)

Figure 4.8. Photographs from 2019 showing: (a) mounting configuration of radar ground speed sensor, center of digger, and high-speed camera, to the right of the radar sensor; and (b) imposed transect line bisecting experimental plots, which provided visual indication for use in toggling high speed photography and subsequent analysis of camera vine speed.

Above Ground Loss Collection

Prior to combining, above ground digging losses were collected in both years of testing along the intersection of the transect(s) with each plot. Above ground losses were collected by hand in a 2.4 m (8 ft) by two row (1.9 m, 6.3 ft) area in 2018 and in a 1.2 m (4 ft) by two row (1.9m, 6.3ft) area in 2019. At the sample area, the windrow was carefully rolled back to expose the ground below and was replaced in its original position for combining after losses were collected. After rolling back the windrow, a PVC frame was placed over the center of the two rows and defined the sample area. Above ground digging losses were described as any pod that could be seen without disturbance of the soil; these pods were collected from within the sample area.

In the 2018 test year above ground losses were separated into two above ground loss categories: over mature and diseased losses (OMD) and mechanical losses. The study defined over mature and diseased pods as those which still had a segment of the peg attached, and generally frayed or otherwise broken along the length of the peg, visible signs of over maturity (purplish discolorations), or visible signs of disease (generally soft, black exocarp tissue). Mechanical losses were defined as pods that had visible tearing of the peg from the pod; the presence of a “star” or portion of a “star” at the peg attachment point indicated a mechanical loss (Chapin et al., 2005). The description provided above resulted in consistent categorization of losses.

All above ground loss samples for both years were oven dried using a modified ASABE S410.3 Alternate Whole Pod Method (ASABE Standards, 2020) procedure as discussed earlier for recovered yield samples. All above ground losses are reported in these studies are dry weights.

Inversion ratings

Along a designated length of windrow inversion ratings, the percentage of poorly inverted rows was determined as the length of row containing plants with taproots outside of 45 degrees of either side of a vertical axis. In the 2018 test year inversion ratings were collected between each of the transects (transects A to B, B to C) in all 108 plots; inversion ratings were observed along a length of 61 meters (200 ft) of row length, equating to 30.5 meters (100.0 ft) of windrow. In the 2019 test year inversion ratings were observed in 84 plots, each rating representing a length of 74 m (244 ft) of row length or 37 m (122 ft) of windrow length, centered within the plot.

Statistical Analysis

Statistical analyses were conducted using one-way ANOVA, and means comparisons were conducted using Student's t-tests (α= 0.05). Recovered yield, above ground losses, above ground mechanical losses, and inversion ratings were investigated within each of the two years of study. The 2018 and 2019 data sets were subjected to the same criteria for statistical analysis. All statistical analyses were performed under the following procedures. Data sets were confirmed to be from a normal distribution using the Shapiro-Wilk w-test for goodness of fit (α= 0.05). If rejected for normalcy, transformations were performed with Box-Cox transformations (Ott et al., 2010). If not rejected for normalcy, the data transformation procedure was omitted. Next, an outlier analysis was performed; outliers were excluded from any given ANOVA or means comparison using constraints of Tukey's 1.5 inter quartile range rule (Ott et al., 2010). A one-way ANOVA and a Student's t-test were performed upon completion of procedures above. Statistical analysis was performed in JMP pro v.14.1.0 statistical software (SAS Institute Inc., Cary, N.C.).

Although the procedures for statistical analyses were designed to address the occurrence of data found to not be normally distributed, the listed procedures did not normalize distributions in all cases. In instances where normalization could not be obtained through outlier analysis and box-cox transformations, summary statistics were reported. The reported summary statistics for non-normal data include treatment means, standard error, and Shapiro-Wilk w-test for goodness of fit W-value and P-value.

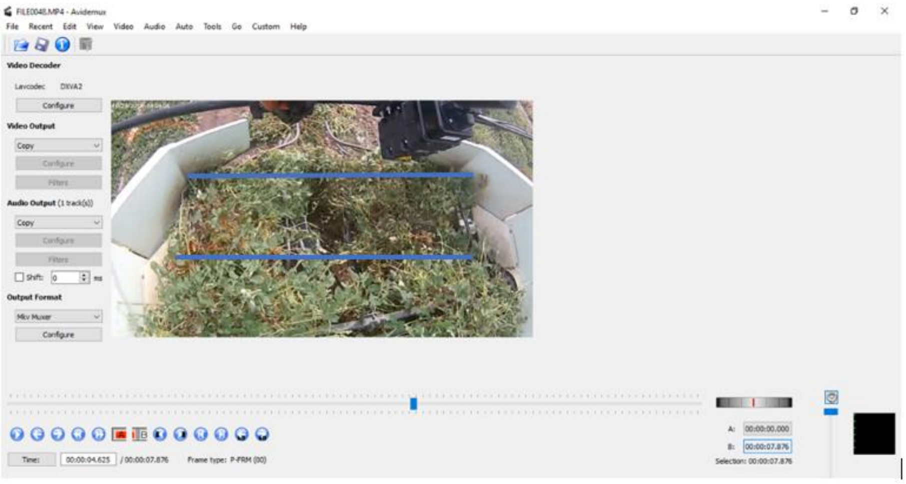
Analysis of variance and means comparison were omitted for these datasets, since these analyses are only valid for normally distributed datasets.

Analysis of Vine Speed at Inversion

To determine the reliability and validity of each vine speed measurement method (radar and high speed camera) and effect of treatments on vine speeds, analyses utilizing one-way ANOVA and Student's t-tests were performed. Procedures outlined previously in the statistical analysis section of this chapter were completed on measured vine speed (radar and camera) within both years of testing.

Video recordings from the high-speed camera were uploaded to Avidemux v.2.7.4 (Free Software Foundation, Inc., Boston, Mass.), a video editing application that allowed for videos to be analyzed on a frame-by-frame basis. Utilizing the orange transect painted on the canopy and references of known distance from one another on the digger, the time of plant travel across the defined distance within the digger was recorded. When the marked plants crossed the first reference on the digger the video timestamp was recorded as the starting time and the video was advanced frame-by-frame until the marked plants reached the second reference on the digger (Figure 4.9) at which point the video timestamp was recorded as the ending time. The known distance between references was divided by time of travel (calculated as ending time minus starting time) to determine vine speed prior to inversion as measured using the camera. Data logs containing GPS positions and radar speed sensor outputs were uploaded into Farm Works Software (Trimble Navigation Limited, Sunnyvale, Cal.). The georeferenced radar vine speed data was identified within plot boundaries and trimmed to include only those data points recorded within 3.1 m (10.0 ft) of either side of the transect lines (Figure 4.10). These data points were averaged for each plot-transect intersection and used for analysis, herein known as average radar vine speed.

Simple linear regression models were fit in JMP pro v.14.1.0 statistical software (SAS Institute Inc., Cary, North Carolina). Linear regression models were constructed under the following procedures. Independent and dependent variables used in the model were confirmed to be from a normal distribution using the Shapiro-Wilk w-test for goodness of fit ($\alpha = 0.05$). If rejected for normalcy, transformations were performed with Box-Cox transformations (Ott et al., 2010). If not rejected for normalcy, the data transformation procedure was omitted. Next, an outlier analysis was performed on both independent and dependent variables; outliers were excluded using constraints of Tukey's 1.5 inter quartile range rule (Ott et al., 2010). Once outliers were eliminated simple linear regression models were constructed. Regression outliers were removed considering Cook's D statistic (Ott et al., 2010). Upon exclusion of outlier's models were reconstructed.



Video Decoder
Lavcodec DXVA2

Video Output
Copy

Audio Output (1 track(s))
Copy
☐ Shift: 0 ms

Output Format
Mkv Muxer

Time: 00:00:04.625 / 00:00:07.876 Frame type: P-FRM (00)

A: 00:00:00.000
B: 00:00:07.876
Selection: 00:00:07.876

Figure 4.9. Screen capture of Avidemux application utilized to determine the camera vine speeds, with added blue reference lines indicating timing of plant travel starting and stopping points. In this figure, the orange spray-painted transect line is crossing the first blue reference line, indicating the starting time for the vine speed analysis at this plot-transect intersection.

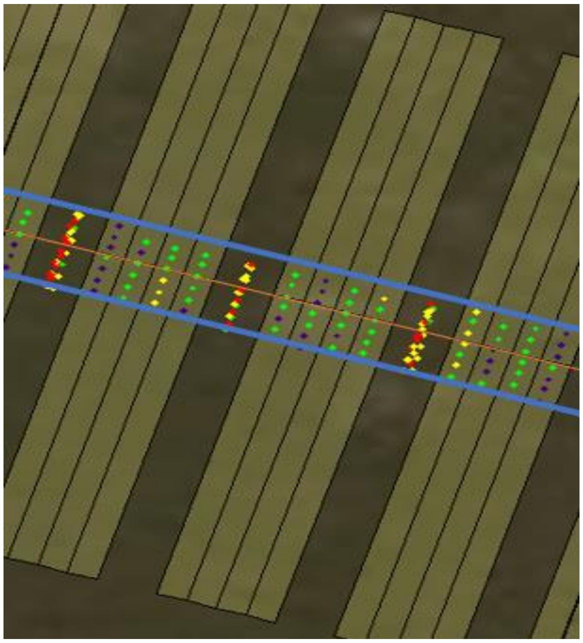


Figure 4.10. Example of georeferenced radar vine speed data within experimental plots and trimmed to only include points within 3.1 m (10.0 ft) of the orange transect line.

Results and Discussion

The two-year study was conducted to determine the effects of vine load on peanut digging operations and investigate the potential application of vine speed sensing to indicate the potential for inversion related losses. Results are separated by investigational objectives: Vine Mass Control Strategies, Mechanical Vine Load Compensation Strategies, and Methods to Monitor Vine Load Conditions, for each year of testing. Comparisons between study years were not conducted due to differences in planting year, crop conditions, and field locations.

Vine Mass Control Strategies

The study objectives under Vine Mass Control Strategies investigated the effects of the application of the plant growth regulator Apogee (prohexadione calcium), mechanical mowing of vines, and an untreated check treatment on the peanut digging process to quantify the effects of vine mass control strategies on recovered yield, above ground digging losses and inversion.

2018 Vine Mass Control

Total above ground losses were found to be significant across vine mass control treatments for the 2018 test year at the α=0.10 significance level ($F_{2,316} = 2.3734$, p= 0.0948). Average total above ground losses ranged from 100 kg ha^{-1} (89 lb ac^{-1}) to 113 kg ha^{-1} (101 lb ac^{-1}) for the vine mass control treatments (Table 4.1). The overall effect of mechanical mowing strategy to reduce vine mass on total above ground losses was significant. Means comparison between treatments indicated that the mean total above ground losses for the mechanically mowed treatments were significantly lower than the untreated check treatments by 9 kg ha^{-1} (8 lb ac^{-1}). The lowest mean total above ground losses were achieved by the vine mass reduction method of mechanically mowing vines. The highest numerical mean total above ground losses were incurred by the Apogee vine treatment. However, there were no statistical differences between the untreated check and the Apogee treatments. These findings demonstrate that methods of reducing vine mass can significantly reduce above ground digging losses across a wide range of digger operating conditions.

Table 4.1. Mean total above ground losses (kg ha^{-1}) as a function of vine mass control strategy treatment for the 2018 test year. ($F_{2,316} = 2.3734$, p= 0.0948)

Vine Mass Control Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping α=0.05 [a] (α=0.10 [b])	SE (kg ha^{-1})
Untreated Check	105	109	A (A)	4.2
Apogee	106	113	A (A)	4.2
Mowed	108	100	A (B)	4.1

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Above ground losses collected in the 2018 test year were separated into losses caused by mechanical influence or over maturity and disease (OMD) as defined earlier. Significant differences between treatments on mechanical above ground losses were not found in the study. The summary of mechanical above ground losses provided in Table 4.2 indicates the average above ground mechanical losses ranged from 23 kg ha^{-1} (21 lb ac^{-1}) to 31 kg ha^{-1} (28 lb ac^{-1}) for the vine mass control treatments. The highest numerical mean mechanical above ground losses were incurred by the mowed treatment, and lowest mean mechanical above ground losses were incurred by the Apogee treatment ($F_{2,270} = 0.2303$, p= 0.7944). Apogee vine mass control treatments were not significantly different but resulted in 6 kg ha^{-1} (5 lb ac^{-1}) lower average mechanical digging losses than the untreated check vine treatments. These findings, although not significant, are contrasting the total (combined mechanical and OMD losses) above ground losses discussed previously, where mechanically mowing vines significantly reduced losses.

Further investigation of OMD above ground losses reiterated the findings presented earlier where total above ground losses were examined. Mechanical mowing of vines demonstrated significantly lower above ground OMD losses; a means comparison indicated 12 kg ha^{-1} (11 lb ac^{-1}) and 14 kg ha^{-1} (13 lb ac^{-1}) lower mean OMD above ground losses for the mowed treatment versus the untreated check and Apogee treatments, respectively. The findings suggest that vine mass reduction methods may effectively reduce total above ground losses but does not support that both methods resulted in lower average mechanical digging losses, which could be due to the classification some true mechanical digging losses as OMD losses.

Table 4.2. Mean above ground mechanical losses (kg ha^{-1}) as a function of vine mass control treatment in the 2018 test year. ($F_{2,270}$ = 0.2303, p = 0.7944)

Vine Mass Control Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Untreated Check	107	29	A	3.3
Apogee	106	23	A	3.3
Mowed	107	31	A	3.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.3. Mean above ground OMD losses (kg ha^{-1}) as a function of vine mass control treatment in the 2018 test year. ($F_{2,299}$ = 4.7927, p = 0.0089)

Vine Mass Control Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Untreated Check	101	82	A	3.3
Apogee	100	84	A	3.3
Mowed	101	70	B	3.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Analysis for the 2018 test year inversion ratings were conducted on a non-normal data set (W= 0.851314, p <0.0001). The frequency of properly inverted plants throughout the observed row length resulting in numerous 0% ratings, resulting in a narrow inner quartile range, and a skewed distribution, resulting in a lack of normalcy. The statistical procedure outlined in this study provided methods to transform non-normal data in an effort to achieve a normal distribution. However, transformation procedures outlined in this study did not allow for the normalization of data in this instance. Reporting of the effects of 2018 vine mass control strategies on inversion ratings is strictly to provide a statistical summary of inversion ratings by vine mass control treatment; statistical comparisons using the methods in this study would be invalid based on the assumptions of the statistical tests used. Average inversion ratings as a percentage of poorly inverted windrows ranged from 1.9% to 3.5% for the 2018 test year. Methods of vine mass reduction resulted in lower numerical mean inversion ratings. Table 4.4 provides a summary of these findings.

Table 4.4. Mean inversion ratings (% poorly inverted) as a function of vine mass control strategy treatment for the 2018 test year[a].

Vine Mass Control Treatment	N	Mean Inversion Ratings (% Poor Inversion)	SE (% Poor Inversion)
Untreated Check	71	3.5	0.20
Apogee	72	1.9	0.20
Mowed	72	3.2	0.20

[a] Unable to normalize (W= 0.851314, p < 0.0001).

2019 Vine Mass Control

Average recovered yield ranged from 3,406 kg ha^{-1} (3,039 lb ac^{-1}) to 3,681 kg ha^{-1} (3,284 lb ac^{-1}) for the vine mass control treatments in the 2019 test year. The overall effect of vine mass control treatments on yield recovery were significant. A means comparison demonstrated that recovered yields for the Apogee treatment was statistically greater (α=0.10) than those for the untreated check by 275 kg ha^{-1} (245 lb ac^{-1}) (Table 4.5). Table 4.5 also indicates that the mean recovered yield for the mowed treatment was numerically but not significantly higher than that for the untreated check treatment by 161 kg ha^{-1} (143 lb ac^{-1}). These findings are in alignment with the Beam et al. (2002)

study, which reported increased yields and improved digging efficiency with the application of prohexadione calcium. Further, considering a peanut value of \$441 metric ton^{-1} (\$400 ton^{-1}), substantial value is suggested by the two methods which reduce vine mass over the untreated check treatment. The revenue difference between the Apogee treatment and the untreated check was \$121 ha^{-1} (\$49 ac^{-1}), is exceeded by the cost of Apogee application estimated to be \$166 ha^{-1} (\$67 ac^{-1}) for two three-quarter label rate applications; this is consistent with findings by Monfort et al. (2021) suggesting that the costs of Apogee exceeded the benefits. At the application estimated cost and assumed peanut value, a recovered yield benefit upwards of 376 kg ha^{-1} (334 lb ac^{-1}) would need to be experienced for the application of Apogee to be profitable. Cost of Apogee application was estimated using a product rate of 771 g ha^{-1} (11 oz ac^{-1}), cost of Apogee at \$0.17 g^{-1} (\$4.80 oz^{-1}) (Clemson Extension, 2021), and an application operation cost of \$17 ha^{-1} (\$7 ac^{-1}) per application (Langemeier, 2021). Revenue for the mowed treatment would have exceeded revenue for the untreated check by \$71 ha^{-1} (\$29 ac^{-1}), although recovered yield differences were not found to be significant ($F_{2,72} = 1.444$, $p = 0.2427$); the cost to mow vines prior to digging can be estimated at \$37 ha^{-1} (\$15 ac^{-1}) (Langemeier, 2021). These findings suggest that strategies to reduce vine mass can significantly improve recovered peanut yields and performance of digging operations. Considering the costs to apply Apogee and the costs to mow vines, the data suggest that profitability of vine mass reduction via mowing may be greater than that via Apogee application.

Table 4.5. Mean recovered peanut dry yield (kg ha^{-1}) as a function of vine mass control treatment in the 2019 test year. ($F_{2,72}$ = 1.444, p= 0.2427)

Vine Mass Control Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping α=0.05 [a] (α=0.10 [b])	SE (kg ha^{-1})
Untreated Check	26	3406	A (B)	113.6
Apogee	25	3681	A (A)	115.8
Mowed	24	3567	A (AB)	118.2

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Total above ground losses in the 2019 test year were not found to be significantly different across vine mass control treatments; mean total above ground losses ranged from 101 kg ha^{-1} (89 lb ac^{-1}) to 110 kg ha^{-1} (101 lb ac^{-1}) (Table 4.6, $F_{2,79}$ = 0.1713, p= 0.8429). Mean total above ground losses were numerically lower for the check vine mass control treatments by as much as 9 kg ha^{-1} (8 lb ac^{-1}). The mowed vine mass control treatment resulted in the largest amount of mean above ground losses. Above ground losses were not separated into mechanical above ground losses and OMD losses for the 2019 test year.

Table 4.6. Mean total above ground losses (kg ha^{-1}) as a function of vine mass control treatment in the 2019 test year. ($F_{2,79}$ = 0.1713, p= 0.8429)

Vine Mass Control Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[c]	SE (kg ha^{-1})
Untreated Check	26	101	A	8.8
Apogee	28	108	A	8.5
Mowed	28	110	A	8.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Average inversion ratings for the 2019 test year ranged from 5.9% to 10.0% across the vine mass control treatments. The treatment effects were statistically significant at the α=0.05 level (Table 4.7). Apogee and untreated check treatments were found to have significantly lower inversion ratings (better inversion) than the mowed vine mass control treatment. Apogee treatments achieved a lower mean inversion rating than the mowed treatments by 4.1%. However, the Apogee vine treatment did not indicate significant differences from the check vine mass control treatment, as summarized in

Table 4.7. Significantly increased inversion ratings by the mowed vine treatments may be explained by Young et al. (1982), that indicated peanut diggers do not handle short plants efficiently. Since mechanical mowing reduces vine mass as a function of plant height and considering the observations presented in Young et al. (1982), the height to which plants are mowed may be a critical component to the impact of vine reduction through means of mechanical mowing and its relation to yield recovery.

Table 4.7. Mean inversion ratings (% poor inversion) as a function of vine mass control treatment for the 2019 test year. ($F_{2,81}$ = 5.7468, p= 0.0046)

Vine Mass Control Treatment	N	Mean Inversion Ratings (% Poor Inversion)	T-Test Grouping[a]	SE (% Poor Inversion)
Untreated Check	28	6.3	B	0.78
Apogee	28	5.9	B	0.78
Mowed	28	10.0	A	0.78

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Mechanical Vine Load Compensation Strategies

The objectives encompassed in the Mechanical Vine Load Compensation Strategies component of the study investigated the effects of mechanically manipulated vine load during digging. Varying inversion rod spacing and conveyor speed settings were used determine the effects of treatments on recovered yield, above ground digging losses and inversion.

2018 Mechanical Vine Load Compensation Strategies

The effects of the five conveyor speed treatments from the 2018 test year demonstrated significant effects on total above ground losses at the α=0.05 significance level. Average total above ground losses ranged from 98 kg ha^{-1} (87 lb ac^{-1}) to 116 kg ha^{-1} (104 lb ac^{-1}) for the five conveyor speed treatments (Table 4.8). Mean total above ground losses were minimized at the 89% and 100% conveyor speed control treatments as compared to the lowest (65%) and highest (115%) conveyor speeds tested where above ground losses were greatest. Above ground losses for the 76% conveyor speed setting were not significantly different from any other conveyor speed tested. The overall magnitude of separation between the mean total above ground losses were found to range from 10 kg ha^{-1} (9 lb ac^{-1}) to 18 kg ha^{-1} (17 lb ac^{-1}) between the treatments. The differences in average total above ground losses was largest between the 89% conveyor speed treatment and the 65% conveyor speed treatment, indicating an 18 kg ha^{-1} (17 lb ac^{-1}) improvement at the 89% conveyor speed setting. These findings are summarized in Table 4.8.

Table 4.8. Mean total aboveground losses (kg ha^{-1}) as a function of conveyor speed treatment for the 2018 test year. ($F_{4,314}$ = 2.6964, p = 0.0309)

Conveyor Speed Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
65%	54	116	A	5.8
76%	52	106	AB	6.0
89%	53	98	B	5.9
100%	81	103	B	4.8
115%	79	113	A	4.8

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Analysis of the separation of total above ground losses into above ground mechanical losses is presented in Table 4.9. Collected above ground mechanical losses across conveyor speed control treatments were not from a normal distribution (W= 0.961612, $p < 0.0001$). The summary of mean above ground mechanical losses generally follow the findings of conveyor speed effect on total above ground losses presented in Table 4.8. Mean above ground mechanical losses were numerically lowest at the 89% and 100% conveyor speed treatments.

Table 4.9. Mean above ground mechanical losses (kg ha^{-1}) as a function of conveyor speed treatment for the 2018 test year [a].

Conveyor Speed Treatment	N	Mean Above Ground Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})
65%	53	29	4.516
76%	54	30	4.474
89%	54	25	4.474
100%	81	27	3.653
115%	81	29	3.653

[a] Unable to normalize ($W=0.961612$, $p < 0.0001$).

Analysis of mean above ground OMD losses indicated significant differences between the 89% conveyor treatment and the 115% conveyor vine control treatment (Table 4.10). These findings were in agreement with the findings of conveyor speed effects on total above ground losses discussed earlier. While the imposed treatments do not directly affect maturity or disease incidence, the data suggest that digging operations could impact losses associated with overmature and diseased pods. Several studies note that peg strength is reduced as a function of maturity and disease pressure and highlight the negative impacts of reduced peg strength on digging operations (Chapin et al., 2005; Colvin et al., 2018; Grichar et al., 1998; Thomas et al.,1983; Troeger et al., 1976). As an additional consideration, the procedure defined in this study for categorization of above ground losses as mechanically induced losses or overmature and diseased losses would fail to identify the proportion of pods that resulted in pod detachment as a function of mechanical influence along the length of the peg—i.e., some of the pods classified as OMD may in fact have been retained but were detached due to mechanical action by the digger. Therefore, it is hypothesized that digging and digger settings mechanically dislodge a portion of overmature and diseased losses that may have otherwise had strong enough pegs to remain attached to the vine; a portion of pods categorized as above ground OMD losses are actually lost as a function of mechanical influence and therefore represent potentially marketable pods. Furthermore, overmature pods that can be retained would theoretically increase grade, since kernels are fully developed. Analysis of mechanical treatment effects on OMD losses such as that provided in Table 4.10 should be regarded as meaningful with respect to effect on revenue and market value. This consideration is made under the assumption that peanuts were under similar growth conditions imposed by the experimental design, crop management practices, digging dates, and disease pressure are consistent across replications and the true proportion of OMD pods are consistent within replications.

Table 4.10. Mean above ground OMD losses (kg ha^{-1}) as a function of conveyor speed treatment for the 2018 test year. ($F_{4,303}$ = 1.7117, p= 0.1472)

Conveyor Speed Treatment	N	Mean OMD Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
65%	51	81	AB	4.905
76%	49	79	AB	5.004
89%	52	70	B	4.858
100%	80	76	AB	3.916
115%	76	85	A	4.018

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The effect of rod spacing was found to significantly impact total above ground losses across treatments for the 2018 test year at the α=0.05 significance level. Table 4.11 provides a summary of mean total above ground losses across the three rod spacing control treatments, ranging from 97 kg ha^{-1} (87 lb ac^{-1}) for standard rod spacing to 122 kg ha^{-1} (109 lb ac^{-1}) for narrow rod spacing (Table 4.11). Narrow rod spacing increased total above ground losses by 25 kg ha^{-1} (22 lb ac^{-1}) and 17 kg ha^{-1} (15 lb ac^{-1}) when compared to standard and wide rod spacings, respectively. Rod spacing was manipulated in this study in an effort to artificially constrict and relax vine flow as a way of simulating similar effects to vine flow noted to occur under heavy vine load conditions. Rod spacing is typically adjusted in an effort to improve inversion and windrow structure; as such, the method of rod spacing adjustment is not likely to be adopted into production practices, despite any indicated situational benefits of the treatments. Although application as a means of vine control is not likely, these findings indicate the importance of proper attention to maintain proper or slightly wider rod spacing. As mentioned, the application of rod spacing treatments in this study also allowed for the effect of vine load on vine flow to be examined despite vine conditions. Conceivably, narrow rod spacing treatments would simulate effects of rods at standard spacings under heavy vine conditions, wide rod spacing treatments would likely suggest effect of inversion assembly on losses under light vine conditions. If narrow rod spacing is a suitable proxy to simulate effects of heavy vine loads, then these data support the hypothesis that the inversion assembly is responsible for increased losses in heavy vine loads presented in chapter 3.

Table 4.11. Mean total above ground losses (kg ha^{-1}) as a function of rod spacing treatment for the 2018 test year. ($F_{2,316}$ = 11.1314, $p < .0001$)

Rod Spacing Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Narrow	108	122	A	4.036
Standard	131	97	B	3.664
Wide	80	105	B	4.689

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Mechanically influenced losses across rod spacing control treatments failed to satisfy normality criteria for analysis of variance and means comparison (W=0.961612, $p < 0.0001$). The summary of above ground mechanical losses provided in Table 4.12, which indicate the average above ground mechanical losses ranged from 37 kg ha^{-1} (33 lb ac^{-1}) to 21 kg ha^{-1} (19 lb ac^{-1}). A 16 kg ha^{-1} (14 lb ac^{-1}) difference in mean above ground mechanical losses is realized for the standard and narrow rod spacing treatments, agreeing with the findings presented in Table 4.11.

Table 4.12. Mean above ground mechanical losses (kg ha^{-1}) as a function of rod spacing treatment for the 2018 test year [a].

Rod Spacing Treatment	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})
Narrow	108	37	3.1
Standard	134	21	2.8
Wide	81	27	3.6

[a] Unable to normalize (W=0.961612, $p < 0.0001$).

Above ground OMD losses as a function of rod treatments indicated significantly lower losses (α=0.10) for the standard rod spacing treatments (74 kg ha^{-1}, 66 lb ac^{-1}) when compared to narrow rod treatments (85 kg ha^{-1}, 76 lb ac^{-1}). The wide rod spacing treatment demonstrated 8 kg ha^{-1} (7 lb ac^{-1}) lower above ground OMD losses when compared to narrow rod spacing treatments; OMD losses for wide and narrow rod spacing treatments were not found to be statistically different. The reported means are in general agreement with the findings of the influence of rod treatments on total above ground losses. The summary of above ground OMD losses can be found in Table 4.13.

Table 4.13. Mean above ground OMD losses (kg ha^{-1}) as a function of rod spacing treatment for the 2018 test year. ($F_{2,305}$ = 1.9651, p = 0.1419)

Rod Spacing Treatment	N	Mean OMD Losses (kg ha^{-1})	T-Test Grouping α=0.05 [a] (α=0.10 [b])	SE (kg ha^{-1})
Narrow	99	85	A (A)	3.5
Standard	131	74	A (B)	3.1
Wide	78	77	A (AB)	4.0

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

The effect of the five conveyor speed treatments within each of the three vine mass control strategies (untreated check, Apogee, and mowed) were analyzed for the 2018 test year. Conveyor speed treatments under the Apogee vine treatment were found to significantly affect mean total above ground losses at the α=0.05 significance level. Average total above ground losses were found to be lowest at the 89% and 100% conveyor speed settings; mean total above ground losses across the five conveyor speed treatments under the Apogee treatments ranged from 101 kg ha^{-1} (90 lb ac^{-1}) to

131 kg ha^{-1} (117 lb ac^{-1}), illustrated in Table 4.14. The greatest level of total above ground losses under the Apogee vine mass control treatments was incurred at the 115% conveyor speed treatments. Conveyor speeds under the untreated check and mowed vine speed treatments were not found to significantly reduce losses at any setting. However, the magnitude of mean total above ground losses were numerically lowest at the 89% conveyor speed control treatments under the untreated check ($F_{4,97}$=0.1964, p=0.9397) and mowed ($F_{4,103}$=0.8728, p=0.4830) vine mass control treatments. These data suggest that even when vine mass is reduced through the application of Apogee plant growth regulator, conveyor speeds can significantly impact total above ground digging losses.

Table 4.14. Mean total above ground losses (kg ha^{-1}) as a function of conveyor speed treatment, by vine mass control treatment for the 2018 crop year.

	Untreated Check $F_{4,97}$=0.1964, p=0.9397			Apogee Vine Mass Control $F_{4,101}$=2.1657, p=0.0782			Mowed Vine Mass Control $F_{4,103}$=0.8728, p=0.4830		
Conveyor Speed Treatment	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) α=0.05 [a] (α=0.10 [b])	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
65%	17	105 A	8.6	18	121 AB (AB)	11.7	18	111A	9.1
76%	16	112 A	8.9	18	103 AB (ABC)	11.7	18	103A	9.1
89%	17	99 A	8.6	18	101 B (C)	11.7	18	93A	9.1
100%	26	111 A	7.0	27	103 B (BC)	9.6	27	97A	7.4
115%	26	111 A	7.0	25	131 A (A)	9.9	27	100A	7.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Above ground mechanical losses as a function of conveyor speed treatment (Table 4.15) for the three vine mass treatments could not be transformed to a normal distribution for statistical analysis within two of the vine mass treatments (untreated check treatment: W=0.945153, p=0.0002; mowed treatment: W=0.953610, p=0.0009). There were no significant differences in above ground mechanical losses as a function of conveyor speed in the Apogee vine mass control treatment. A summary of the above ground mechanical losses, instead, as a function of vine mass control treatment within each of the conveyor speeds is provided in Table 4.16. The data in Table 4.16 do not allow for comparisons between conveyor speed treatments but do suggest the effects of vine load at various conveyor speeds. The influence on mechanical losses as a function of vine mass control strategy was not found to have significant effects at any conveyor speed. However, mean above ground mechanical losses were numerically lowest for the Apogee treatments in four out of the five tested conveyor speeds: 65% ($F_{2,41} = 0.3087$, p= 0.7361), 76% ($F_{2,42} = 0.0503$, p= 0.951), 89% ($F_{2,45} = 0.0608$, p= 0.9411), and 100% ($F_{2,64} = 0.3951$, p= 0.6752). The lowest numerical mean in Tables 4.15 and 4.16 was achieved under the Apogee vine treatments at 89% conveyor speed control treatment; from Table 4.16, these losses were equal to 18 kg ha^{-1} (16 lb ac^{-1}).

Table 4.15. Mean above ground mechanical losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three vine mass control treatments for the 2018 test year.

	Untreated Check [a]			Apogee Vine Mass Control $F_{4,100}$ =0.5768, p=0.6801			Mowed Vine Mass Control [c]		
Conveyor Speed Treatment	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1}) [b]	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})
65%	18	40	9.3	18	21 A	4.8	18	35	9.1
76%	18	37	9.3	18	24 A	4.8	18	29	9.1
89%	18	25	9.3	17	16 A	4.9	18	33	9.1
100%	27	26	7.6	27	24 A	3.9	27	32	7.4
115%	27	24	7.6	25	26 A	4.1	27	33	7.4

[a] Unable to normalize (W=0.945153, p=0.0002).

[b] Treatments with the same letter indicate no significant differences (α=0.05).

[c] Unable to normalize (W=0.953610, p=0.0009).

Table 4.16. Mean above ground mechanical losses (kg ha^{-1}) as a function of vine mass control strategy treatment within each of the five conveyor speeds tested in the 2018 test year.

	65% Conveyor Speed $F_{2,41}$ = 0.3087, p= 0.7361			76% Conveyor Speed $F_{2,42}$ = 0.0503, p= 0.951			89% Conveyor Speed $F_{2,45}$ = 0.0608, p= 0.9411		
Vine Mass Control Treatment	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Untreated Check	16	44A	10.8	13	50A	9.9	17	26A	6.2
Apogee	15	24A	11.2	18	23A	8.4	15	18A	6.6
Mowed	13	46A	12.0	14	36A	9.5	16	27A	6.4

	100% Conveyor Speed $F_{2,64}$ = 0.3951, p= 0.6752			115% Conveyor Speed $F_{2,63}$ = 1.0312, p= 0.3625		
Untreated Check	22	30A	6.8	20	31A	7.4
Apogee	24	26A	6.5	24	32A	6.8
Mowed	21	40A	7.0	22	39A	7.1

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Analyses of mean above ground OMD losses are reported in Table 4.17. Under the Apogee vine mass control strategy, OMD losses were significantly lower (α=0.05) for the 100% conveyor speed treatment (79 kg ha^{-1}; 71 lb ac^{-1}) than the 115% conveyor speed treatment (104 kg ha^{-1}; 93 lb ac^{-1}). Significant differences were not present across remaining conveyor speed treatments under various vine mass control strategies. Conveyor speed control treatments under the untreated check ($F_{4,103}$ =0.6992, p=0.5942) and mowed ($F_{4,87}$ =0.6320, p=0.6410) vine mass control treatments, both achieved the lowest numerical means at the 89% conveyor speed settings. While not statistically comparable from the arrangement of data in Table 4.17, it is noted that mean above ground OMD losses for the mowed treatment are generally lower than those for the untreated check and those for the Apogee treatment are generally higher than those for the untreated check.

Table 4.17. Mean above ground OMD losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three vine mass control treatments for the 2018 test year.

	Untreated Check $F_{4,103}$ =0.6992, p=0.5942			Apogee Vine Mass Control $F_{4,101}$ =1.7111, p=0.1534			Mowed Vine Mass Control $F_{4,87}$ =0.6320, p=0.6410		
Conveyor Speed Treatment	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1})[a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
65%	17	80A	8.2	18	100 AB	10.7	14	63A	5.8
76%	14	80A	9.1	18	79 AB	10.7	16	73A	5.4
89%	18	71A	8.0	18	85 AB	10.7	16	66A	5.4
100%	27	83A	6.5	27	79 B	8.8	23	67A	4.5
115%	26	87A	6.7	25	104 A	9.1	23	71A	4.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Means comparisons of total above ground losses as a function of the mechanical vine load control treatments of wide, narrow, and standard rod spacings displayed a significant effect on average total above ground losses under all three vine mass control strategies (Table 4.18). Standard rod spacing was significantly lower than narrow rod spacing under all vine mass control strategies. Average total above ground losses as a function of rod spacing under the various vine mass control strategies resulted in total above ground losses ranging from 92 kg ha^{-1} (82 lb ac^{-1}) to 135 kg ha^{-1} (120 lb ac^{-1}). Total above ground losses for standard rod spacing treatments averaged 98 kg ha^{-1} (87 lb ac^{-1}) under check vine mass control, 96 kg ha^{-1} (86 lb ac^{-1}) under Apogee vine mass control, and 92 kg ha^{-1} (82 lb ac^{-1}) under mowed vine mass control. The mowed vine mass control generally resulted in the lowest numerical means at respective rod spacing control treatments. The highest numerical mean total above ground losses were reported under the Apogee vine mass control strategy.

Table 4.18. Mean total above ground losses (kg ha^{-1}) as a function of rod spacing treatment within each of the three vine mass control treatments for the 2018 test year.

	Untreated Check $F_{2,99} = 3.5109$, p= 0.0336			Apogee Vine Mass Control $F_{2,105} = 7.3426$, p= 0.001			Mowed Vine Mass Control $F_{2,105} = 1.9002$, p= 0.1546		
Rod Spacing Treatment	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) α=0.05[a] (α=0.10[b])	SE (kg ha^{-1})
Narrow	36	120 A	5.4	36	135 A	8.3	36	110 A(A) [e]	5.6
Standard	40	98 B	6.7	45	96B	10.7	45	92 A(B) [e]	7.3
Wide	26	107 AB	5.7	27	120 AB	9.2	27	100 A(AB) [e]	6.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

The above ground mechanical losses data summary reported in Table 4.19 is from datasets which could not be transformed to a normal distribution (untreated check treatment: W= 0.945153, p= 0.0002; Apogee treatments: W=0.970921, p= 0.0181; mowed treatment: W= 0.945932, p= 0.0003). Statistical comparisons can therefore not be made using the methods outlined in this study. Reported mean above ground mechanical losses were in general higher for the narrow rod spacing treatments. Further, mean above ground mechanical losses across all vine mass treatments were typically lower for the standard rod treatments. Further analysis of mechanical loss data for comparisons as a function of vine mass control treatment within each rod spacing treatment is provided in Table 4.20. Under the wide rod spacing strategy, the resultant analysis indicated a significant reduction in average above ground mechanical losses for the Apogee treatments as compared to the mowed treatments (α=0.05). The conditions presented in this combination of treatments is believed to represent the lightest vine load conditions. Therefore, the significant reduction in mechanical losses (17 kg ha^{-1}; 15 lb ac^{-1}) is supportive of a positive relationship between above ground mechanical losses and vine load. Effects of vine mass control treatments on above ground mechanical losses were not found to be significant under the narrow ($F_{2,90}$= 0.2586, p= 0.7727) or standard

($F_{2,109}$ = 0.3147, p= 0.7307) rod spacing treatments. However, Apogee vine mass treatments achieved the lowest mean above ground mechanical losses within both the narrow and standard rod spacing control strategy groupings. The largest numerical mean above ground mechanical losses were reported under the untreated check vine mass control treatments and narrow rod control strategy, or presumably representing the heaviest induced vine loads tested.

Table 4.19. Mean above ground mechanical losses (kg ha^{-1}) as a function of rod spacing treatment within each of the three vine mass control treatments for the 2018 test year.

	Untreated Check [a]			Apogee Vine Mass Control [b]			Mowed Vine Mass Control [c]		
Rod Spacing Treatment	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})
Narrow	36	41	6.5	36	32	3.6	36	38	6.2
Standard	45	22	5.8	45	22	3.2	45	24	5.6
Wide	27	26	7.5	27	15	4.2	27	39	7.2

[a] Unable to normalize (W=0.945153, p= 0.0002).
[b] Unable to normalize (W=0.970921, p= 0.0181).
[c] Unable to normalize (W=0.945932, p= 0.0003).

Table 4.20. Mean above ground mechanical losses (kg ha^{-1}) as a function of vine mass control treatment within each of the three rod spacing treatments for the 2018 test year.

	Narrow Rod Spacing $F_{2,90}$= 0.2586, p= 0.7727			Standard Rod Spacing $F_{2,109}$ =0.3147, p=0.7307			Wide Rod Spacing $F_{2,65}$ =4.0422, p=0.0222		
Vine Mass Control Treatment	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Untreated Check	29	50A	7.2	37	26A	5.2	22	31AB	6.5
Apogee	33	34A	6.7	39	24A	5.0	23	17B	6.4
Mowed	31	43A	6.9	36	28A	5.2	23	44A	6.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Rod spacing treatments within groups of vine mass control treatments indicated a range of 61 kg ha^{-1} (54 lb ac^{-1}) to 106 kg ha^{-1} (95 lb ac^{-1}) in above ground OMD losses (Table 4.21). When rod spacing treatments under untreated check ($F_{2,99}$= 0.1697, p= 0.8441) and mowed ($F_{2,95}$= 0.4564, p= 0.6350) vine mass control groupings were considered, the data failed to demonstrate statistical differences in above ground OMD losses. Under the Apogee vine mass control treatment, rod spacing significantly influenced OMD losses (α=0.05). These findings reiterated increased losses under narrow rod spacing treatments and reduced losses with standard rod spacing treatments.

Rod spacing treatments within groups of vine mass control treatments indicated a range of 61 kg ha^{-1} (54 lb ac^{-1}) to 106 kg ha^{-1} (95 lb ac^{-1}) in above ground OMD losses (Table 4.21). When rod spacing treatments under untreated check ($F_{2,99}$=0.1697, p=0.8441) and mowed ($F_{2,95}$=0.4564, p=0.6350) vine mass control groupings were considered, the data failed to demonstrate statistical differences in above ground OMD losses. Under the Apogee vine mass control treatment, rod spacing significantly influenced OMD losses (α=0.05). These findings reiterated increased losses under narrow rod spacing treatments and reduced losses with standard rod spacing treatments.

Table 4.21. Mean above ground OMD losses (kg ha^{-1}) as a function of rod spacing treatment within each of the three vine mass control treatments for the 2018 test year.

	Untreated Check $F_{2,99}$= 0.1697, p= 0.8441			Apogee Vine Mass Control $F_{2,102}$ = 4.1813, p= 0.0180			Mowed Vine Mass Control $F_{2,95}$ = 0.4564, p= 0.6350		
Rod Spacing Treatment	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Narrow	33	79A	5.9	35	106A	7.4	29	67A	4.5
Standard	43	82A	5.2	44	75B	6.6	42	67A	3.7
Wide	26	81A	6.7	26	94AB	8.6	27	61A	4.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Analysis of the effect of conveyor speeds at various rod spacings was performed. Total above ground losses were found to be significantly influenced by conveyor speed treatments under the standard rod spacing treatment for the 2018 test year at the α=0.05 significance level (Table 4.22). Average total above ground losses ranged from 85 kg ha^{-1} (79 lb ac^{-1}) to 126 kg ha^{-1} (112 lb ac^{-1}) across conveyor speed control treatments and rod spacing groupings. A significant reduction in above ground losses was determined for the 89% and 100% conveyor speeds compared to the 115% conveyor speed within the standard rod spacing treatment. Also, within this grouping, total above ground losses were significantly increased by 26 kg ha^{-1} (23 lb ac^{-1}) and 14 kg ha^{-1} (13 lb ac^{-1}) at the 115% and 65% conveyor speed treatments, respectively, compared to the 100% conveyor speed treatment. A means comparison showed a 25 kg ha^{-1} (22 lb ac^{-1}) detriment when conveyor speed treatments were increased from 89% to 115% in the standard rod spacing grouping. No significant differences were indicated across other groupings as outlined in Table 4.22. While not statistically comparable to the other rod spacing groupings as the data is structured in Table 4.22, the mean total above ground losses was consistently higher under the narrow rod grouping than in the other groupings. However, there were no statistical differences between the conveyor speed treatments under this grouping. These findings point further to support an optimal conveyor speed of 89% to 100% of ground speed for the test conditions.

Table 4.22. Mean total above ground losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three rod spacing treatments for the 2018 test year.

	Narrow Rod Spacing $F_{3,104}$ = 0.2945, p = 0.8293			Standard Rod Spacing $F_{4,125}$ = 2.8587, p = 0.0262			Wide Rod Spacing $F_{2,77}$ = 0.5125, p = 0.6010		
Conveyor Speed Treatment	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
65%	27	126 A	8.7	26	99 AB	6.7	-	-	-
76%	27	115 A	8.7	25	96 ABC	6.8	-	-	-
89%	-	-	-	26	86 BC	6.7	18	109 A	8.5
100%	26	122 A	8.7	27	85 C	6.5	27	102 A	8.5
115%	26	125 A	8.7	26	111 A	6.7	25	103 A	8.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

The summary provided in Table 4.23 reports above ground mechanical losses, which could not be transformed to a normal distribution for statistical comparisons. The reported mean above ground mechanical losses were slightly lower at conveyor speeds of 89% and 100% under standard rod spacing. Although they cannot be statistically compared to the other groupings as presented, mean above ground mechanical losses were, for any given conveyor speed, consistently largest for the narrow rod spacing treatments.

Table 4.23. Mean above ground mechanical losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three rod spacing treatments for the 2018 test year.

	Narrow Rod Spacing [a]			Standard Rod Spacing [b]			Wide Rod Spacing [c]		
Conveyor Speed Treatment	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})	N	Mean Mechanical Losses (kg ha^{-1})	SE (kg ha^{-1})
65%	27	36	7.6	25	18	3.5	-	-	-
76%	27	36	7.6	26	19	3.4	-	-	-
89%	-	-	-	26	13	3.4	27	33	6.1
100%	27	40	7.6	27	16	3.3	27	26	6.1
115%	27	37	7.6	26	24	3.4	27	21	6.1

[a] Unable to normalize (W=0.953319, p= 0.0008).
[b] Unable to normalize (W=0.941314, p< 0.0001).
[c] Unable to normalize (W=0.954351, p= 0.0058).

Significant differences in above ground OMD losses as a function of conveyor speed were not found within any rod spacing (Table 4.24). Mean above ground OMD losses ranged from 70 kg ha^{-1} (63 lb ac^{-1}) to 90 kg ha^{-1} (80 lb ac^{-1}) across conveyor speed treatments at various rod spacing treatments. The minimum OMD losses were reported at 89% conveyor speeds with standard rod spacing ($F_{4,122}$=0.4532, p=0.7699). Overall, the numerical values reported in Table 4.24 follow the findings of analyses previously discussed, which suggest a reduction of losses at the 89% to 100% conveyor speed settings and standard rod spacing.

Table 4.24. Mean above ground OMD losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three rod spacing treatments for the 2018 test year.

	Narrow Rod Spacing $F_{3,104} = 0.2221, p = 0.8809$			Standard Rod Spacing $F_{4,122} = 0.4532, p = 0.7699$			Wide Rod Spacing $F_{2,76} = 0.9941, p = 0.3748$		
Conveyor Speed Treatment	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean OMD Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
65%	27	90A	9.3	27	78A	4.9	-	-	-
76%	27	79A	9.3	24	74A	5.2	-	-	-
89%	-	-	-	26	70A	5.0	27	76A	8.2
100%	27	81A	9.3	25	73A	5.1	27	76A	8.2
115%	27	88A	9.3	25	78A	5.1	25	85A	8.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.25 and Table 4.26 report mean inversion ratings as functions of conveyor speed and rod spacing treatments, respectively. Neither dataset was able to be transformed to a normal distribution; statistical comparisons can therefore not be made. The reported mean inversion ratings were numerically lowest (best inversion) at 100% conveyor speed, and percentage of poor inversion was numerically highest at 65% conveyor speed. Mean inversion ratings were numerically lowest for the standard rod treatments and displayed the numerically highest percentage of poorly inverted plants at the narrow rod spacing.

Table 4.25. Mean inversion ratings (% Poor Inversion) as a function of conveyor speed treatment for the 2018 test year. [a]

Conveyor Speed Treatment	N	Mean Inversion Rating (% Poor Inversion)	SE (% Poor Inversion)
65%	36	5.7	0.47
76%	35	3.8	0.48
89%	36	2.3	0.47
100%	54	1.3	0.29
115%	54	2.4	0.29

[a] Unable to normalize ($W=0.851314, p < 0.0001$).

Table 4.26. Mean inversion ratings (% Poor Inversion) as a function of rod spacing treatment for the 2018 test year. [a]

Rod Spacing Treatment	N	Mean Inversion Rating (% Poor Inversion)	SE (% Poor Inversion)
Narrow	89	3.7	0.13
Standard	54	2.2	0.31
Wide	72	2.5	0.20

[a] Unable to normalize ($W=0.851314, p < 0.0001$).

2019 Mechanical Vine Load Compensation Strategies

Average recovered yield ranged from 3,380 kg ha^{-1} (3,016 lb ac^{-1}) to 3,669 kg ha^{-1} (3,273 lb ac^{-1}) for the 2019 test year. The overall effect of conveyor speed treatments on yield recovery was not significant (Table 4.27). Despite no significant differences, a mean recovered yield difference of 289 kg ha^{-1} (258 lb ac^{-1}) was recognized between the 100% conveyor speed treatment (3,669 kg ha^{-1}; 3,273 lb ac^{-1}) and the 85% conveyor speed treatment (3,380 kg ha^{-1}; 3,016 lb ac^{-1}) ($F_{3,71} = 0.9163$, $p = 0.4375$). Further, analysis of this relationship of yield recovery and revenue, considering a peanut value of \$441 metric ton^{-1} (\$400 ton^{-1}), suggests a value difference of \$127 ha^{-1} (\$52 ac^{-1}) between the treatments. These findings are similar to a 2017 study where yields were maximized at the 100% conveyor settings under normal vine growth conditions (Kirk et al., 2017).

Table 4.27. Mean recovered peanut dry yield (kg ha^{-1}) as a function of conveyor speed treatment for the 2019 test year. ($F_{3,71} = 0.9163$, $p = 0.4375$)

Conveyor Speed Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	19	3634	A	133.9
85%	18	3380	A	137.6
100%	18	3669	A	137.6
115%	20	3514	A	130.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Considering the interaction between conveyor speed treatments and vine mass control strategies in the 2019 test year, average recovered yields were not significantly affected by conveyor speed (Table 4.28). Under the Apogee vine mass control grouping, recovered yields ranged from 3,548 kg ha^{-1} (3,165 lb ac^{-1}) at 85% conveyor speed to 3,825 kg ha^{-1} (3,412 lb ac^{-1}) at 100% conveyor speed ($F_{3,21} = 0.2673$, $p = 0.8482$). Research plots under the mowed vine grouping had an average recovered yield as large as 3,780 kg ha^{-1} (3,372lb ac^{-1}) at 70% conveyor speed and as low as 3,375 kg ha^{-1}

(3,011 lb ac^{-1}) at 85% conveyor speed ($F_{3,20}$ = 0.3056, p= 0.8210). Under the mowed vine mass control grouping, the second largest mean recovered yield was noted to occur at 100% conveyor speed. Further, the untreated check grouping resulted in the lowest value average recovered yield at 85% conveyor speed (3,239 kg ha^{-1}; 2,890 lb ac^{-1}) and largest at 100% conveyor speed (3,552 kg ha^{-1}; 3,169 lb ac^{-1}) ($F_{3,22}$ =0.3573, p=0.7844). While the structure of Table 4.28 does not support statistical comparisons between vine mass control groupings, the magnitude of average recovered yield was typically lower for the untreated check treatments than the two methods of vine mass control at any given conveyor speed. A large amount of variability was present in the recovered yields resulting in lack of statistically significant means comparisons; however, a potential trend exists where the numerically greatest yield recovery was demonstrated at 100% conveyor speed in each of the three vine mass control groupings.

Table 4.28. Mean recovered peanut dry yield (kg ha^{-1}) as a function of conveyor speed treatment within each of the three vine mass control treatments for the 2019 test year.

	Untreated Check $F_{3,22}$ =0.3573, p=0.7844			Apogee Vine Mass Control $F_{3,21}$ =0.2673, p=0.8482			Mowed Vine Mass Control $F_{3,20}$ =0.3056, p=0.8210		
Conveyor Speed Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (kg ha^{-1})
70%	6	3447A	227.7	7	3669A	195.1	6	3780A	295.9
85%	7	3239A	210.8	6	3548A	210.8	5	3375A	324.1
100%	6	3552A	227.7	5	3825A	230.9	6	3658A	273.9
115%	7	3414A	210.8	7	3703A	195.1	7	3409A	295.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Total above ground losses as a function of conveyor speed were found to significantly differ across treatments for the 2019 test year (α=0.05). Average total above ground losses ranged from 94 kg ha^{-1} (84 lb ac^{-1}) to 124 kg ha^{-1} (111 lb ac^{-1}) (Table 4.29). The 85% conveyor speed demonstrated 30 kg ha^{-1} (27 lb ac^{-1}) less losses than the 115% conveyor speed. Further, comparison failed to indicate significant advantages of the 85%

conveyor speed over the 100% and 70% conveyors speeds. Considering the data previously discussed in Table 4.28, the differences in total above ground losses do not explain the lower mean recovered yields at the 85% conveyor speed settings.

Table 4.29. Mean total above ground losses (kg ha^{-1}) as a function of conveyor speed treatment for the 2019 test yea. ($F_{3,78}$= 2.1562, p= 0.0999)

Conveyor Speed Treatment	N	Mean Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	20	96	AB	9.776
85%	21	94	B	9.541
100%	21	112	AB	9.541
115%	20	124	A	9.776

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Conveyor speed treatments were found to significantly impact mean total above ground losses when grouped by Apogee and untreated check vine mass control in the 2019 test year. Significant differences were not indicated in total above ground losses as a function of conveyor speeds within the mowed vine mass control grouping. Table 4.30 indicates that mean total above ground losses were minimized at the 85% conveyor speed treatments (85 kg ha^{-1}; 76 lb ac^{-1}) within the Apogee grouping (α=0.05). In the same grouping, 70% (108 kg ha^{-1}; 96 lb ac^{-1}) and 100% (97 kg ha^{-1}; 86 lb ac^{-1}) conveyor speed treatments did not demonstrate significantly different losses than those at 85% conveyor speed. Within the untreated check grouping, 70% conveyor speed incurred minimal losses (79 kg ha^{-1}; 71 lb ac^{-1}). However, the 85% (99 kg ha^{-1}; 88 lb ac^{-1}) and 115% (98 kg ha^{-1}; 87 lb ac^{-1}) conveyor speeds did not show significantly different losses from those at 70% conveyor speed (α=0.10). Within the untreated check grouping, total above ground losses at 100% conveyor speed were significantly higher than those at 70% conveyor speed. Mean total above ground losses when vine mass was reduced as a function of the two vine mass control treatments, mowed or Apogee, for the four conveyor speeds settings were generally lower when compared to the untreated check treatments (Table 4.30). Further, a general trend of lower numerical mean total above ground losses at slower conveyor speed settings and increased losses with the two higher conveyor speed settings was demonstrated in Table 4.31 ($F_{3,23}$=0.7205, p=0.5500). It should be noted when comparing reported mean total above ground loss values across vine mass treatments over the 85% and 100% conveyor speed treatments, the magnitude of losses is lower under the Apogee vine mass controls. Although comparatively, greater magnitudes of losses are reported at the 70% and 115% conveyor speed treatments under the Apogee vine mass treatments than the untreated check and mowed vine mass controls.

Table 4.30. Mean total above ground losses (kg ha^{-1}) as a function of conveyor speed treatment within each of the three vine mass control treatments in the 2019 test year.

	Untreated Check $F_{3,23}$ = 1.3075, p= 0.2960			Apogee Vine Mass Control $F_{3,24}$ = 2.5015, p= 0.0835			Mowed Vine Mass Control $F_{3,23}$ = 0.7205, p= 0.5500		
Conveyor Speed Treatment	N	Mean Above Ground Losses (kg ha^{-1}) α=0.05[a] (α=0.10[b])	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
70%	7	79A(B)	14.682	7	108AB	15.970	7	91A	17.118
85%	7	99A(AB)	14.682	7	85B	15.970	7	97A	17.118
100%	7	116A(A)	14.682	7	97AB	15.970	7	124A	17.118
115%	6	98A(AB)	15.859	7	142A	15.970	6	109A	18.49

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.31. Mean total above ground losses (kg ha^{-1}) as a function of vine mass control strategy for four conveyor speed treatments in the 2019 test year.

	70% Conveyor speed treatment $F_{2,18} = 0.9678$, p= 0.3988			85% Conveyor speed treatment $F_{2,18} = 0.252$, p= 0.7799		
Vine Mass Control Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Apogee	7	108A	14.7	7	85A	15.6
Untreated check	7	79A	14.7	7	99A	15.6
Mowed	7	91A	14.7	7	97A	15.6
	100% Conveyor speed treatment $F_{2,17} = 0.5412$, p= 0.5918			115% Conveyor speed treatment $F_{2,17} = 0.0926$, p= 0.912		
Vine Mass Control Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Apogee	7	97A	13.5	7	142A	26.0
Untreated check	7	116A	13.5	6	142A	28.0
Mowed	6	108A	14.6	7	129A	26.0

[a] Treatments with the same letter indicate no significant differences (α=0.05)

Average inversion ratings for the 2019 test year ranged from 5.8% to 10.2% across the conveyor speed treatments and were statistically significant at the α=0.05 level (Table 4.32). The 70% conveyor speed treatments were found to have significantly higher inversion ratings (poorer inversion) than the higher speed conveyor treatments. Inversion ratings for the 85%, 100%, and 115% conveyor speeds were not significantly different from one another, although the 100% conveyor speed treatment numerically demonstrated the best inversion rating. These findings may suggest that inversion as a function of conveyor speed was optimized when synchronized with ground speed, or at 100% conveyor speed; deviation in conveyor speed from ground speed may have negatively influenced inversion. The benefits of properly inverted rows have been noted to include improved crop drying and reduction of losses at combining (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968).

Table 4.32. Mean inversion ratings (% Poor Inversion) as a function of conveyor speed treatment for the 2019 test year. ($F_{2,80}$ = 4.200, p= 0.0082)

Conveyor Speed Treatment	N	Mean Inversion Ratings (% Poor Inversion)	T-Test Grouping[b]	SE (% poor inversion)
70%	21	10.2	A	0.918
85%	21	6.4	B	0.918
100%	21	5.8	B	0.918
115%	21	7.2	B	0.918

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Methods to Monitor Vine Load Conditions

Analysis of variance and means comparison tests were performed on vine speed readings for both methods of monitoring vine speed (camera and radar) across both test years to determine if detectable speed differences were significant as a function of vine load control or compensation strategy.

One-way ANOVA and Student's t-test analyses were applied to monitored radar, camera vine speeds, and a speed ratio between the measured vine speeds and the conveyor speed as functions of vine mass control and mechanical vine load compensation treatments. It should be noted that the magnitudes of mean radar speeds reported in the 2018 and 2019 study are relative to the study year and do not allow for comparison between the two years (speeds were not calibrated between years).

Vine speed measured by both the camera and radar were found to be significantly affected by conveyor speed in both years of testing. These results can be found in Tables 4.33 – 4.36. This clearly demonstrates that conveyor speed is influential to vine velocity in later stages of the digging process after discharge from the conveyor. It should also be noted in Table 4.33- 4.36 that the influence of conveyor speed setting was not measurably different for all conveyor treatments, indicated by the lack of means separation, although this could have been influenced by the vine mass control treatments and the rod spacing treatments.

Table 4.33. Mean radar speed (kph) as a function of conveyor speed treatment in the 2018 test year. ($F_{4,61} = 31.8564$, $p < 0.0001$)

Conveyor Speed Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
65%	8	3.4	D	0.08
76%	13	3.7	C	0.07
89%	8	4.0	B	0.08
100%	23	4.0	B	0.05
115%	14	4.4	A	0.06

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.34. Mean camera speed (kph) as a function of conveyor speed treatment in the 2018 test year. ($F_{4,61} = 11.4147$, $p < 0.0001$)

Conveyor Speed Treatment	N	Mean Speed (kph)	T-Test Grouping[b]	SE (kph)
65%	8	1.2	D	0.16
76%	13	1.8	C	0.12
89%	8	1.8	BC	0.16
100%	23	2.1	B	0.09
115%	14	2.3	A	0.12

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.35. Mean radar speed (kph) as a function of conveyor speed treatment in the 2019 test year. ($F_{3,77} = 226.1351$, $p < 0.0001$)

Conveyor Speed Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
70%	19	2.1	D	0.04
85%	21	2.5	C	0.04
100%	21	2.8	B	0.04
115%	20	3.3	A	0.04

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.36. Mean camera speed (kph) as a function of conveyor speed treatment. ($F_{3,75} = 18.926$, $p < 0.0001$)

Conveyor Speed Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
70%	19	1.1	C	0.07
85%	21	1.5	B	0.07
100%	19	1.7	A	0.07
115%	20	1.7	A	0.07

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Monitored radar vine speed was found to be significantly different as a function of rod spacing treatments overall, where wide rod spacing resulted in significantly (α=0.05) higher vine speeds (Table 4.37). Further, no significant differences in camera vine speeds were indicated as a function of rod spacing (Table 4.38). Considering conveyor speed treatments, in the 2018 test year only, groupings of two conveyor speeds (100% and 115%) allowed for comparison of the effect of rod spacing on measured vine speed. Table 4.39 demonstrated no significant influence on monitored radar speed as a function of rod spacing grouped by the 100% and 115% conveyor speeds. In Table 4.40, significant (α=0.05) differences were demonstrated between camera vine speeds as a function of rod spacing grouped by the same conveyor speeds previously mentioned. The findings indicate for groupings of 100% conveyor speed, standard rod spacing resulted in significantly higher speeds. For groupings of 115% conveyor speeds wide rod spacings were found to be significantly higher. The overall significant difference in radar vine speed suggests that rod spacing significantly impacts the vine speed; in this study the imposition of rod spacing treatments allowed for simulation of rod and the inversion assembly interactions with heavy vine loads. For wide rod spacing treatments, reduced vine load was simulated; therefore, measured vine speed effects due to rod spacing may be considered a function of vine load and rod spacing interaction. These findings also suggest that the radar speed sensor can effectively differentiate the effects of speed due to interactions of vine load with the inverter rod assembly.

Table 4.37. 2018 Mean radar speed (kph) by mechanical vine load control strategy treatment. ($F_{1,64} = 4.2168$, $p = 0.0441$)

Rod Spacing Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Standard	45	3.9	B	0.06
Wide	21	4.1	A	0.09

[b] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.38. 2018 Mean camera speed (kph) by mechanical vine load control strategy treatment. ($F_{1,64} = 0.3316$, $p = 0.5668$)

Rod Spacing Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Standard	45	1.9	A	0.08
Wide	21	2.0	A	0.12

[b] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.39. Mean radar speed (kph) as a function of rod spacing for two conveyor speed treatments in the 2018 test year.

	100% Conveyor Speed $F_{1,20} = 0.3412$, p= 0.5657				115% Conveyor Speed $F_{1,10} = 0.7445$, p= 0.4084			
Rod Spacing Treatment	N	Mean Speed	T-Test Grouping[a]	SE	N	Mean Speed	T-Test Grouping[a]	SE
Standard	14	6.5	A	0.07	7	7.3	A	0.10
Wide	8	6.4	A	0.09	5	7.2	A	0.12

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.40. Mean camera speed (kph) as a function of rod spacing for two conveyor speed treatments in the 2018 test year.

	100% Conveyor Speed $F_{1,21} = 14.7649$, p= 0.0009				115% Conveyor Speed $F_{1,13} = 12.2028$, p= 0.004			
Rod Spacing Treatment	N	Mean Speed	T-Test Grouping[a]	SE	N	Mean Speed	T-Test Grouping[a]	SE
Standard	15	3.6	A	0.14	9	3.4	B	0.19
Wide	8	2.7	B	0.20	6	4.5	A	0.23

[a] Treatments with the same letter indicate no significant differences (α=0.05).

A speed ratio between the monitored radar and camera vine speeds versus the conveyor speed was calculated, where measured vine speed was divided by conveyor speed. The resultant ratio is believed to indicate a direct relationship of measured vine speed and the conveyor speed in the monitored area.

Camera vine speed versus conveyor ratio was not found to be significantly different as a function of rod spacing treatments overall (Table 4.41). Further, no significant differences in radar vine speeds vs. conveyor ratios as a function of rod spacing were found (Table 4.42). Groupings of rod spacing treatments by the two conveyor speeds (100% and 115%) demonstrated significant differences in camera speed vs. conveyor speed ratios. Table 4.43 indicated findings of higher speed ratios as a function of standard rod spacing for 100% conveyor speeds and higher speed ratios as a function of wide rod spacing for 115% conveyor speeds.

The data from the mean radar vine speed vs. conveyor ratio as a function of rod spacing treatments was not able to be transformed to a normal distribution; statistical comparisons were not made between these treatments. These results can be referenced in Appendix B.

Table 4.41. Mean camera speed vs. conveyor ratio as a function of rod spacing treatments in the 2018 test year. ($F_{1,65}$ = 0.953, p= 0.3326)

Rod Spacing Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Standard	45	0.9	A	0.02
Wide	22	0.8	A	0.04

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.42. Mean radar speed vs. conveyor ratio as a function of rod spacing for two conveyor speed treatments in the 2018 test year.

	100% Conveyor Speed				115% Conveyor Speed			
	$F_{1,21}$ = 0.0185, p= 0.8931				$F_{1,10}$ = 0.7445, p= 0.4084			
Rod Spacing Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Standard	15	1.6	A	0.02	7	1.6	A	0.02
Wide	8	1.6	A	0.03	5	1.5	A	0.03

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.43. Mean camera speed vs. conveyor ratio as a function of rod spacing for two conveyor speed treatments in the 2018 test year.

	100% Conveyor Speed				115% Conveyor Speed			
	$F_{1,21}$ = 14.7649, p= 0.0009				$F_{1,13}$ = 12.2028, p= 0.004			
Rod Spacing Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Standard	15	0.9	A	0.04	9	0.7	B	0.04
Wide	8	0.7	B	0.05	6	1.0	A	0.05

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Tables 4.44 – 4.47 summarize vine speed as a function of vine mass control treatment. These treatments were not found to significantly affect vine speed overall when monitored under the radar or camera method (Tables 4.44-4.47). Further, considering measured vine speeds as a function of vine mass control grouped by conveyor speed, vine mass control treatments were found to significantly influence monitored radar and camera vine speeds in the 2018 test year (Table 4.48-4.49). Demonstrating that deviation in vine velocity due to vine mass can be effectively sensed within the defined area monitored when conveyor speed is considered. In the 2019 test year vine speed monitored by the radar or camera was not found to be significantly influenced as a function of vine mass control treatments for groupings of four conveyor speed treatments (Table 4.50- 4.51). Further, the effect of vine mass reduction is likely small on monitored vine speed in relatively normal or light vine loads, which are typical of the runner varieties tested. Therefore, variability in measured vine speed may need to be reduced to better determine differences in vine speed. A greater averaging distance is suggested to reduce the impact of variability. Under excessive vine loads such as those commonly encountered in Virginia type peanuts, it is hypothesized that larger differences in vine velocity would be evident and more easily measured.

Table 4.44. Mean radar speed (kph) as a function of vine mass control strategy treatments for the 2018 test year. ($F_{2,63}$ = 0.2496, p= 0.7799)

Vine Mass Control Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Apogee	23	4.0	A	0.09
Untreated Check	23	3.9	A	0.09
Mowed	20	4.0	A	0.09

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.45. Mean camera speed (kph) as a function of vine mass control strategy treatments for the 2018 test year. ($F_{2,63}$ = 1.1176, p= 0.3335)

Vine Mass Control Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Apogee	23	2.0	A	0.12
Untreated Check	23	2.0	A	0.12
Mowed	20	1.8	A	0.13

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.46. Mean radar speed (kph) as a function of vine mass control strategy treatments for the 2019 test year. ($F_{2,78}$ = 0.2926, p= 0.7471)

Vine Mass Control Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Apogee	27	2.7	A	0.10
Untreated Check	27	2.6	A	0.10
Mowed	27	2.7	A	0.10

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.48. Mean radar speed (kph) as a function of vine mass control strategy for five conveyor speed treatments for the 2018 test year.

	65% Conveyor Speed $F_{2,5}$ = 1.4439, p= 0.3199			76% Conveyor Speed $F_{2,10}$ = 4.0513, p= 0.0514			89% Conveyor Speed $F_{2,5}$ = 8.4744, p= 0.0248		
Vine Mass Control Treatment	N	Mean speed (kph) [a]	SE (kph)	N	Mean speed (kph) [a]	SE (kph)	N	Mean speed (kph) [a]	SE (kph)
Apogee	3	5.2A	0.18	6	6.1A	0.07	3	6.7A	0.15
Untreated Check	3	5.6A	0.18	3	6.3AB	0.10	3	5.9B	0.15
Mowed	2	5.6A	0.22	4	5.9B	0.08	2	6.7A	0.19

	100% Conveyor Speed $F_{2,18}$ = 1.3472, p= 0.285			115% Conveyor Speed $F_{2,9}$ = 1.5178, p= 0.2704		
Apogee	8	6.6A	0.07	3	7.4A	0.14
Untreated Check	7	6.5A	0.08	4	7.1A	0.13
Mowed	6	6.4A	0.08	5	7.3A	0.11

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.49. Mean camera speed (kph) as a function of vine mass control strategy for five conveyor speed treatments for the 2018 test year.

	65% Conveyor Speed $F_{2,5}$ = 7.1081, p= 0.0345			76% Conveyor Speed $F_{2,10}$ = 1.966, p= 0.1905			89% Conveyor Speed $F_{2,5}$ = 2.3385, p= 0.1919		
Vine Mass Control Treatment	N	Mean speed (kph) [a]	SE (kph)	N	Mean speed (kph) [a]	SE (kph)	N	Mean speed (kph) α=0.05[a] (α=0.10[b])	SE (kph)
Apogee	3	2.1A	0.06	6	3.1A	0.17	3	2.7A(A)	0.38
Untreated check	3	2.1A	0.06	3	2.8A	0.25	3	3.6A(AB)	0.38
Mowed	2	1.7B	0.08	4	2.5A	0.21	2	2.4A(B)	0.46

	100% Conveyor Speed $F_{2,20}$ = 2.9992, p= 0.0726			115% Conveyor Speed $F_{2,12}$ = 0.0327, p= 0.9679		
Apogee	8	3.8A	0.23	3	3.7B	0.48
Untreated check	8	3.1AB	0.23	6	3.9A	0.34
Mowed	7	3.1B	0.25	6	3.9AB	0.34

[a] Treatments with the same letter indicate no significant differences (α=0.05).

[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.50. Mean radar speed (kph) as a function of vine mass control strategy for four conveyor speed treatments for the 2019 test year.

	70% Conveyor speed treatment $F_{2,76} = 1.1283$, p= 0.3289			85% Conveyor speed treatment $F_{2,14} = 0.3756$, p= 0.6936		
Vine Mass Control Treatment	N	Mean Speed (kph) [a]	SE (kph)	N	Mean Speed (kph) [a]	SE (kph)
Apogee	5	3.3A	0.10	5	3.3A	0.10
Untreated check	7	3.4A	0.09	7	3.4A	0.09
Mowed	5	3.4A	0.10	5	3.4A	0.10
	100% Conveyor speed treatment $F_{2,14} = 1.1425$, p= 0.347			115% Conveyor speed treatment $F_{2,70} = 0.3419$, p= 0.7116		
Vine Mass Control Treatment	N	Mean Speed (kph) [a]	SE (kph)	N	Mean Speed (kph) [a]	SE (kph)
Apogee	7	4.4A	0.10	24	4.4A	0.15
Untreated check	5	4.6A	0.12	25	4.3A	0.15
Mowed	5	4.6A	0.12	24	4.4A	0.15

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.51. Mean camera speed (kph) as a function of vine mass control strategy for four conveyor speed treatments for the 2019 test year.

	70% Conveyor speed treatment $F_{2,76} = 1.1283$, p= 0.3289			85% Conveyor speed treatment $F_{2,15} = 0.4004$, p= 0.6777		
Vine Mass Control Treatment	N	Mean Speed (kph) [a]	SE (kph)	N	Mean Speed (kph) [a]	SE (kph)
Apogee	5	1.9A	0.17	5	1.9A	0.17
Untreated check	7	1.7A	0.14	7	1.7A	0.14
Mowed	6	1.7A	0.15	6	1.7A	0.15
	100% Conveyor speed treatment $F_{2,14} = 0.4349$, p= 0.6558			115% Conveyor speed treatment $F_{2,71} = 0.5596$, p= 0.5739		
Vine Mass Control Treatment	N	Mean Speed (kph) [a]	SE (kph)	N	Mean Speed (kph) [a]	SE (kph)
Apogee	7	2.6A	0.16	24	2.4A	0.11
Untreated check	5	2.7A	0.19	25	2.3A	0.10
Mowed	5	2.4A	0.19	25	2.3A	0.10

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.52 and Table 4.53 demonstrate vine mass control is overall significantly influential to the ratio of measured vine velocity. Table 4.54 indicates a lack of mean separation, although it should be noted influenced by the methodology of camera vine speed measurement and variability present is likely to have impacted these findings. In both years one method of vine speed sensing indicated significant differences due to vine mass control treatments, suggesting that ratios of measured vine speed and conveyor speed are affected prior to conveyor discharge in the monitored area of the digger.

Measured speed (radar and camera) versus conveyor speed ratio by groupings of conveyor speed indicated similar findings as the mean radar and camera speeds as a function of vine mass control strategies for conveyor speed treatments in both test years (Tables 4.48-4.51). The speed ratios and grouping of conveyor speed treatments are reported in Tables 4.55-4.58, the findings suggest that vine mass control treatments significantly affect radar and camera speed versus conveyor speed ratios. It is suggested due to the nature of the calculations this effect is similar to that measured vine speed, allow for similar uses in the application of vine speed sensing for indicating conditions favorable to inversion related losses.

In 2018 reports of mean radar speed vs. conveyor ratio as a function of vine mass control data were not able to be transformed to a normal distribution; statistical comparisons were therefore not made between treatments. These results can be found in Appendix B.

Table 4.52. Mean camera speed vs. conveyor ratio as a function of three vine mass treatments in the 2018 test year. ($F_{2,64}$ = 2.9431, p= 0.0599)

Vine Mass Control Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Apogee	23	0.9	A	0.03
Untreated check	23	0.8	AB	0.03
Mowed	21	0.8	B	0.04

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.53. Mean radar speed vs. conveyor ratio as a function of three vine mass treatments in 2019. ($F_{2,68}$ = 2.2327, p= 0.115)

Vine Mass Control Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Apogee	25	1.4	AB	0.01
Untreated check	22	1.4	B	0.02
Mowed	24	1.5	A	0.02

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.54. Mean camera speed vs. conveyor ratio as a function of three vine mass treatments in 2019. ($F_{2,66}$ = 0.349, p= 0.7067)

Vine Mass Control Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Apogee	24	0.8	A	0.03
Untreated check	21	0.8	A	0.03
Mowed	24	0.8	A	0.03

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.55. Mean radar speed vs. conveyor ratio as a function vine mass control for five conveyor speed treatments in the 2018 test year.

	65% Conveyor Speed $F_{2,5}$ = 1.4439, p= 0.3199			76% Conveyor Speed $F_{2,10}$ = 4.0513, p= 0.0514			89% Conveyor Speed $F_{2,5}$ = 8.4744, p= 0.0248		
Vine Mass Control Treatment	N	Mean Speed Ratio α=0.05[a] (α=0.10[b])	SE	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	3	2.0A	0.07	6	2.0AB	0.02	3	1.9A	0.04
Mowed	3	2.2A	0.07	3	2.1A	0.03	3	1.7B	0.04
Untreated check	2	2.2A	0.09	4	1.9B	0.03	2	1.9A	0.05

	100% Conveyor Speed $F_{2,20}$ = 1.8069, p= 0.1899			115% Conveyor Speed $F_{2,9}$ = 1.5178, p= 0.2704		
Apogee	8	1.6A (A)	0.02	3	1.6A	0.03
Mowed	8	1.6A (AB)	0.02	4	1.5A	0.03
Untreated check	7	1.6A (B)	0.03	5	1.6A	0.02

[a] Treatments with the same letter indicate no significant differences (α=0.05).

[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.56. Mean camera speed vs. conveyor ratio as a function vine mass control for five conveyor speed treatments in the 2018 test year.

	65% Conveyor Speed $F_{2,5}$ = 7.0258, p= 0.300			76% Conveyor Speed $F_{2,10}$ = 1.966, p= 0.1905			89% Conveyor Speed $F_{2,5}$ = 2.3385, p= 0.1919		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio α=0.05[a] (α=0.10[b])	SE	N	Mean Speed Ratio[a]	SE
Apogee	3	0.8A	0.02	6	1.0A(A)	0.06	3	0.8A	0.11
Mowed	3	0.8B	0.02	3	0.9A(AB)	0.08	3	1.0A	0.11
Untreated check	2	0.7A	0.03	4	0.8A(B)	0.07	2	0.7A	0.13

	100% Conveyor Speed $F_{2,20}$ = 2.9992, p= 0.0726			115% Conveyor Speed $F_{2,12}$ = 0.0327, p= 0.9679		
Apogee	8	0.9A	0.06	3	0.8A	0.10
Mowed	8	0.8AB	0.06	6	0.8A	0.07
Untreated check	7	0.8B	0.06	6	0.8A	0.07

[a] Treatments with the same letter indicate no significant differences (α=0.05).

[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.57. Mean radar speed vs. conveyor ratio as a function of vine load treatments for conveyor speed treatments in the 2019 test year.

	70% Conveyor speed treatment $F_{2,14} = 0.3756$, p= 0.6936			85% Conveyor speed treatment $F_{2,17} = 0.4485$, p= 0.6459		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	5	1.5A	0.05	6	1.5A	0.03
Untreated check	7	1.5A	0.04	7	1.5A	0.03
Mowed	5	1.5A	0.05	7	1.5A	0.03
	100% Conveyor speed treatment $F_{2,14} = 1.1425$, p= 0.347			115% Conveyor speed treatment $F_{2,17} = 0.7558$, p= 0.4848		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	7	1.4A	0.03	7	1.5A	0.02
Untreated check	5	1.4A	0.04	6	1.4A	0.03
Mowed	5	1.4A	0.04	7	1.4A	0.02

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.58. Mean camera speed vs. conveyor ratio as a function of conveyor speed treatment for conveyor speed treatments in the 2019 test year.

	70% Conveyor speed treatment $F_{2,15} = 0.4004$, p= 0.677			85% Conveyor speed treatment $F_{2,16}= 0.2699$, p= 0.7669		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	5	0.8A	0.07	5	0.8A	0.04
Untreated check	7	0.7A	0.06	7	0.8A	0.04
Mowed	6	0.8A	0.07	7	0.8A	0.04
	100% Conveyor speed treatment $F_{2,14} = 0.4349$, p= 0.6558			115% Conveyor speed treatment $F_{2,15} = 0.0035$, p= 0.9965		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	7	0.8A	0.05	6	0.7A	0.03
Untreated check	5	0.8A	0.06	6	0.7A	0.03
Mowed	5	0.7A	0.06	6	0.7A	0.03

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Tables 4.59- 4.60 summarize vine speed as a function of rod spacing. Overall, vine speeds monitored by the radar were not found to be significantly affected by these treatments. However, vine speed measured by the camera as a function of vine mass reduction for the standard rod spacing treatments was found to be significantly (α=0.10) affected (Table 4.60). Under these conditions Apogee vine mass control was found to result in significantly increased speed and ability for detection.

Table 4.59. Mean radar speed as a function of vine mass control for two rod spacing treatments in the 2018 test year.

	Standard Rod treatment $F_{2,40}$ = 0.0269, p= 0.9735				Wide Rod treatment $F_{2,18}$ = 0.2189, p= 0.8055			
Vine Mass Control Treatment	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Apogee	16	6.2	A	0.13	6	6.7	A	0.21
Untreated check	15	6.2	A	0.14	8	6.5	A	0.18
Mowed	12	6.3	A	0.16	7	6.6	A	0.19

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.60. Mean camera speed as a function of vine mass control for two rod spacing treatments in the 2018 test year.

	Standard Rod treatment $F_{2,42}$ = 1.5618, p= 0.2217				Wide Rod treatment $F_{2,19}$ = 0.6928, p= 0.5124			
Vine Mass Control Treatment	N	Mean Speed (kph)	T-Test Groupingα α =0.05[a] (α=0.10[b])	SE (kph)	N	Mean Speed (kph)	T-Test Grouping[a]	SE (kph)
Apogee	17	3.3	A (A)	0.18	6	3.0	A	0.41
Untreated check	15	3.0	A (AB)	0.19	8	3.6	A	0.36
Mowed	13	2.8	A (B)	0.21	8	3.2	A	0.36

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Monitored radar and camera speed versus conveyor speed ratios as a function of vine mass control for two rod spacing treatments were found to be significantly affected. Tables 4.61- 4.63 summarized vine speed ratios as a function of rod spacing for standard and wide rod spacings. The radar speed ratio demonstrated significantly (α=0.10) increased vine speeds when Apogee was applied to the grouping of wide rod spacing treatments (Table 4.61). Vine speed ratios measured by the camera as a function of vine mass reduction for the standard rod spacing treatments were found to significantly (α=0.05) increase as well when Apogee vine mass control treatments were applied. Suggesting reduced vine load is directly related to vine speed in the monitored area. These findings further support the application of a speed versus conveyor ratio in the application of vine speed sensing for indicating conditions favorable to losses.

Table 4.61. Mean radar speed vs. conveyor ratio as a function of vine mass control for two rod spacing treatments in the 2018 test year.

	Standard Rod treatment[c]			Wide Rod treatment $F_{2,19}$ = 1.8355, p= 0.1867			
Vine Mass Control Treatment	N	Mean Speed Ratio	SE	N	Mean Speed Ratio	T-Test Grouping α=0.05[a] (α=0.10[b])	SE
Apogee	17	1.8	0.06	6	1.8	A (A)[b]	0.07
Untreated check	15	1.8	0.07	8	1.6	A (B) [b]	0.06
Mowed	13	1.8	0.07	8	1.7	A (AB) [b]	0.06

[a] Treatments with the same letter indicate no significant differences (α=0.05).

[b] Treatments with the same letter indicate no significant differences (α=0.10).

[c] Unable to normalize (W= 0.9241676, p= 0.0059).

Table 4.62. Mean camera speed vs. conveyor ratio as a function of vine mass control for two rod spacing treatments in the 2018 test year.

	Standard Rod treatment $F_{2,42}$ = 5.7939, p= 0.006				Wide Rod treatment $F_{2,19}$ = 0.6499, p= 0.5333			
Vine Mass Control Treatment	N	Mean Speed Ratio	T-Test Grouping[a]	SE	N	Mean Speed Ratio	T-Test Grouping[a]	SE
Apogee	17	0.9	A	0.03	6	0.8	A	0.08
Untreated check	15	0.8	B	0.03	8	0.9	A	0.07
Mowed	13	0.8	B	0.04	8	0.8	A	0.07

[a] Treatments with the same letter indicate no significant differences (α=0.05).

For consistency between analyses in the two years of study, the relationship between measured speed and speed ratios as function of vine mass control were investigated independently for standard rod spacing grouped by conveyor speeds across the 2018 test year. In 2019 rod spacing was not a treatment factor. Vine mass control was found to significantly affect vine speed monitored by the radar and camera when grouped by conveyor speeds. In tables 4.63-4.64 mean speed measured by the radar and camera is summarized; generally, vine mass control treatments resulted in the highest mean speed and detection where significance was indicated as a function of vine mass control grouped by conveyor speed across both year of study. This was consistent with the previously discussed analyses of speed as a function of vine mass control for conveyor speed treatments. Further, Tables 4.65-4.66 summarize respective speed versus conveyor ratios as a function of vine mass control for standard rod spacing and four conveyor speed treatments. The findings demonstrated similar tendencies of effect as the measured vine speeds previously discussed under similar conveyor speed treatment groupings.

Table 4.63. Mean radar speed (kph) as a function of vine mass control strategy for standard rod spacing and four conveyor speed treatments for the 2018 test year.

	65% Conveyor speed treatment $F_{2,5} = 1.4439$, p= 0.3199			76% Conveyor speed treatment $F_{2,10} = 4.0513$, p= 0.0514		
Vine Mass Control Treatment	N	Mean Speed [a]	SE	N	Mean Speed [a]	SE
Apogee	3	5.2A	0.18	6	6.1AB	0.07
Untreated check	3	5.6A	0.18	3	6.3A	0.10
Mowed	2	5.6A	0.22	4	5.9B	0.08
	100% Conveyor speed treatment $F_{2,11} = 0.388$, p= 0.6874			115% Conveyor speed treatment $F_{2,6} = 3.403$, p= 0.1029		
Vine Mass Control Treatment	N	Mean Speed [a]	SE	N	Mean Speed [a]	SE
Apogee	5	6.6A	0.08	3	7.4A	0.24
Untreated check	5	6.5A	0.08	3	6.6A	0.24
Mowed	4	6.5A	0.09	3	7.2A	0.24

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 4.64. Mean camera speed (kph) as a function of vine mass control strategy for standard rod spacing and five conveyor speed treatments for the 2018 test year.

	65% Conveyor speed treatment $F_{2,5} = 7.1081$, p= 0.0345			76% Conveyor speed treatment $F_{2,10} = 1.966$, p= 0.1905		
Vine Mass Control Treatment	N	Mean Speed [a]	SE	N	Mean Speed α=0.05[a] (α=0.10[b])	SE
Apogee	3	1.7A	0.12	6	3.1A(A)	0.17
Untreated check	3	1.6A	0.12	3	2.8A(AB)	0.25
Mowed	2	1.0B	0.15	4	2.5A(B)	0.21
	100% Conveyor speed treatment $F_{2,11} = 3.3874$, p= 0.0714			115% Conveyor speed treatment $F_{2,6} = 0.6086$, p= 0.5746		
Vine Mass Control Treatment	N	Mean Speed [a]	SE	N	Mean Speed [a]	SE
Apogee	4	3.9A	0.17	3	3.7A	0.37
Untreated check	6	3.4B	0.14	3	3.2A	0.37
Mowed	4	3.4B	0.17	3	3.4A	0.37

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.65. Mean radar speed vs. conveyor speed ratio as a function of vine mass control strategy for standard rod spacing and five conveyor speed treatments for the 2018 test year.

	65% Conveyor speed treatment $F_{2,5}$ = 1.4439, p= 0.3199			76% Conveyor speed treatment $F_{2,10}$ = 4.0513, p= 0.0514		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	3	2.0A	0.07	6	2.0AB	0.02
Untreated check	3	2.2A	0.07	3	2.1A	0.03
Mowed	2	2.2A	0.09	4	1.9B	0.03
	100% Conveyor speed treatment $F_{2,11}$ = 0.9061, p= 0.4322			115% Conveyor speed treatment $F_{2,6}$ = 3.403, p= 0.1029		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio α=0.05[a] (α=0.10[b])	SE
Apogee	4	1.6A	0.03	3	1.6A(A)	0.05
Untreated check	6	1.6A	0.03	3	1.4A(B)	0.05
Mowed	4	1.6A	0.03	3	1.6A(A)	0.05

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Table 4.66. Mean camera speed vs. conveyor speed ratio as a function of vine mass control strategy for standard rod spacing and five conveyor speed treatments for the 2018 test year.

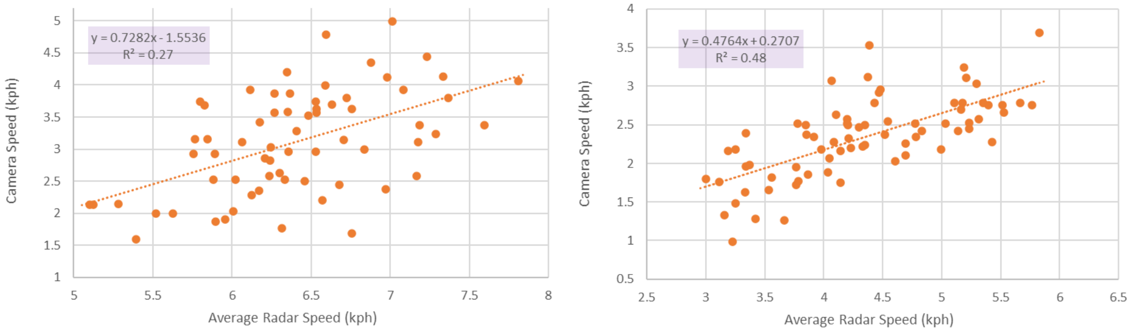
	65% Conveyor speed treatment $F_{2,5}$ = 7.1081, p= 0.0345			76% Conveyor speed treatment $F_{2,10}$ = 1.966, p= 0.1905		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio α=0.05[a] (α=0.10[b])	SE
Apogee	3	0.8A	0.02	6	1.0A (A)	0.06
Untreated check	3	0.8A	0.02	3	0.9A (AB)	0.08
Mowed	2	0.7B	0.03	4	0.8A (B)	0.07
	100% Conveyor speed treatment $F_{2,11}$ = 3.3874, p= 0.0714			115% Conveyor speed treatment $F_{2,6}$ = 0.6086, p= 0.5746		
Vine Mass Control Treatment	N	Mean Speed Ratio [a]	SE	N	Mean Speed Ratio [a]	SE
Apogee	4	1.0A	0.04	3	0.8A	0.08
Untreated check	6	0.9B	0.03	3	0.7A	0.08
Mowed	4	0.8B	0.04	3	0.7A	0.08

[a] Treatments with the same letter indicate no significant differences (α=0.05).
[b] Treatments with the same letter indicate no significant differences (α=0.10).

Linear regression models were fitted to determine if a significant relationship existed between the average vine speed data from the Dickey-john Radar II and the vine speeds measured with the high-speed camera. The fitted linear regressions are provided in Figure 4.11. The two respective linear regressions were overall statistically significant (α=0.05), suggesting that the slope coefficients are non-zero. In 2018 the fitted regression as a function of average radar speed explained 27% of camera speed variation (Figure

4.11a). In 2019 the explanation of variance improved to 48% (Figure 4.11b) and is believed to have been resultant of repositioning of the radar sensor between testing years. In 2018 the Dickey-john Radar II was mounted following factory recommended positioning (Dickey-john, 2017), resulting in the radar face approximately 84 cm (33 in.) directly above the inner-most inversion rotors (starwheels) at approximately 25 degrees to the plane of the plant travel. Repositioning in 2019 resulted in the face of the radar be 10 cm (4 in.) closer to the inner-most inversion rotors (starwheels) or 74 cm (39 in.) above the inner-most inversion rotors (starwheels). In addition, in 2019 the orientation of the radar was changed to 35 degrees on the mount, respective to the plane of plant travel. These position changes were made based on preliminary research discussed earlier in the chapter, where the effective radar cone area was determined. These position changes and improvements in the model are believed to reflect the importance of radar positioning to the measured vine speed. Further, optimization of this position would likely improve the ability of radar use in monitoring vine speed.

The differences in monitored radar speed and measured camera speed should be noted. Monitored radar speeds were averaged over a distance of 6 m (20 ft), while measured vine speed with the camera was instantaneous. Inherently, measured camera vine speeds are more variable due to the collection method, as previously noted in the findings of this study. Although the prediction of camera speed as a function of average radar speed would not be useful in peanut production, the relationship between the two display the ability of the radar to measure and predict speeds of peanut vines within the monitored area of the digger. This suggests potential for its application in peanut harvest and for prediction of conditions within the digger.



(R^2=0.27; $F_{1,64}$ = 23.9858, $p < 0.0001$; β=0.7282, $p < 0.0001$)

(R^2=0.48; $F_{1,71}$ = 64.7824, $p < 0.0001$; β=0.4764, $p < 0.0001$)

(a.) (b.)

Figure 4.11. Simple regression for prediction of instantaneous camera speed (kph) as a function of average radar speed (kph) for 2018 test (a.) and 2019 (b.).

Conclusions

The two-year Effects of Vine Load and Strategies to Address Vine Load Study demonstrated the effects of vine load on above ground losses and recovered yield during the peanut digging process. The study was conducted in effort to provide better understandings of the interactions between vine load as a function of vine mass control, compensation for vine load via digger settings, and relationships with harvest metrics. An investigation of methods to monitor vine load as a function of measured vine speed was performed as a component of this study as well. The understanding of the effects of vine load on digging from the study provide producers with comprehensive approaches in the mitigation of harvest related losses due to vine load interactions with digging operations in various harvest conditions. Analysis of the strategies to reduce vine load in some cases were proven to substantially reduce harvest losses and increase recovered yields; various strategies presented in the study were shown to provide significant advantage, including potential yield retention improvements as large as 8.1%. Conclusions from this study are believed to describe treatment effects which consistently occur but vary in magnitude when accounting for the variability in growing seasons, machinery, physiological properties of the peanut crop and various parameters specific to every harvest situation.

Vine Mass Control Strategies

Objective I was examined in the 2018 and 2019 Vine Mass Control Strategies component, which quantified the effects of three vine mass control strategies on above ground digging losses, recovered yield, and inversion ratings. The three strategies were employed to manipulate vine load prior to digging. Two of the strategies included treatments used to reduce vine load through chemical and mechanical means: the application of the plant growth regulator Apogee (prohexadione calcium) and mechanical mowing of vines. The third strategy was an untreated check (control) treatment.

It can be concluded that vine load as a function of plant vine mass control plays a significant role in influence of the magnitude of above ground losses, recovered peanut yields, and inversion ratings. Improvements to these measures were achieved with implementation of the two vine mass reduction strategies. The influence of vine mass reduction strategies was proven to positively reduce instances of overall above ground losses. Mechanical mowing was found to significantly reduce ($\alpha=0.10$) total above ground losses when compared to check treatments by 9 kg ha^{-1} (8 lb ac^{-1}). Further, the application of Apogee resulted in a general positive impact on mean above ground mechanical losses ($F_{2,270} = 0.2303$, $p = 0.7944$); a numerically lower mean was achieved compared to the Untreated check vine mass control treatment.

In addition to the suggested improvements in above ground losses, Apogee treatments significantly ($\alpha=0.10$) improved recovered yields by 275 kg ha^{-1} (245 lb ac^{-1}) when compared to the untreated check treatments. Mean recovered yield for the mowed treatment was numerically higher ($F_{2,72} = 1.444$, $p = 0.2427$) than that for the untreated check by 161 kg ha^{-1} (143 lb ac^{-1}). By considering a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}) and as compared to the untreated check, these yield differences suggest estimated revenue increases of \$121 ha^{-1} (\$49 ac^{-1}) when Apogee was applied and \$71 ha^{-1} (\$29 ac^{-1}) when vines were mowed ($p > 0.05$).

Furthermore, inversion ratings were shown to be significantly ($\alpha=0.05$) improved by the application of Apogee in the 2019 test year, being reduced by 4.1%. Significant relationships have been documented between proper inversion, harvest related losses and drying efficiency (Duke, 1968; Pearman et al., 1968; Whitney et al., 1968). Improvement in inversion efficiency may relate to the yield improvement and reduced harvest losses seen in this study.

Consistent improvements in performance were reported with the use of both vine mass reduction control strategies. These findings support previous studies, which reported increased yields associated with overall improved digger efficiency, inversion efficiencies, and reductions in excessive vegetative growth (Beam et al., 2002; Jordan, 2008; Studstill et al., 2020). However, the yield benefits indicated in this study and resultant increase in revenue from Apogee application would not exceed the cost of application, estimated at \$166 ha^{-1} (\$67 ac^{-1}) for two three-quarter label rate applications. While yield improvements were not significant for mowing, numerical revenue increases from mowing exceeded the estimated cost to mow (\$37 ha^{-1}; \$15 ac^{-1}). Further research is needed across a wider range of peanut varieties and vine load conditions to determine long term profitability of vine load reduction techniques in efforts to reduce harvest losses while digging. However, a general improvement in above ground losses and recovered yields as a function of vine mass reduction strategies was realized in this study.

Mechanical Vine Load Compensation Strategies

The 2018 and 2019 mechanical vine load compensation strategy component of the two-year study quantified the effects of conveyor speeds (2018 and 2019) and inversion rod spacing treatments in 2018 on digging losses, recovered peanut yield, and inversion ratings. Treatments were designed to manipulate or otherwise simulate effects of various vine loads during digging. The three vine mass control treatments defined in objective I were included. Three inversion rod spacing treatments and five (2018) or four (2019) conveyor speeds (relative to ground speed) were investigated.

Rod spacing treatments were intended in this study to manipulate impediments to vine flow at inversion, with narrow rod spacings simulating vine flow effects for large vine loads; they were not imposed or tested as a strategy for responding to vine load. Rod spacing significantly (α=0.05) affected total above ground losses; narrow rod spacing increased these losses by 17 kg ha^{-1} (15 lb ac^{-1}) to 25 kg ha^{-1} (22 lb ac^{-1}) as compared to standard rod spacing. Compared to standard rod spacing, narrow rod spacing consistently resulted in increased above ground losses overall, although differences were not always significant. These results were reiterated further, when rod spacing treatments were analyzed under the various vine loads imposed by the vine mass control treatments. Narrow rod spacing resulted in significantly increased total above ground losses when compared to standard spacing across all vine mass control treatments (Table 4.18). Under the Apogee treatment, total above ground loss for standard rod spacing was 39 kg ha^{-1} (35 lb ac^{-1}) less than that for the narrow spacing ($p < 0.05$). In the absence of vine mass control treatment, narrow rod spacing increased total above ground loss by 22 kg ha^{-1} (20 lb ac^{-1}) compared to that of standard spacing ($p < 0.05$); in mowed treatments narrow rod spacing increased these losses by 18 kg ha^{-1} (16 lb ac^{-1}) as compared to those for standard spacing ($p < 0.10$). The lack of significant differences in total above ground losses between wide and standard rod spacings suggests that wider spacings were not as impactful on losses. Since rod spacing was used as a method to manipulate vine flow at inversion, these results suggest that impediments to vine flow—such as those imposed by narrow rod spacing or heavy vine loads—can result in increased digging losses.

Additionally, the study concluded that various conveyor speeds significantly influenced above ground losses, recovered peanut yields and inversion ratings. Conveyor speeds were generally optimized at 85% to 100% of ground speed. The five conveyor speeds tested in 2018 demonstrated significant ($\alpha=0.05$) effects on total above ground losses. At 89% and 100% conveyor speeds, these losses were found to be minimized significantly when compared to the 65% and 115% conveyor speed treatments (differences ranged from 10 kg ha^{-1} to 18 kg ha^{-1} depending on comparison). In 2019, the 85% conveyor speed showed total above ground losses to be 30 kg ha^{-1} (27 lb ac^{-1}) less than those for the 115% conveyor speed ($p<0.05$). In 2018, lowest total above ground losses in the Apogee grouping were reported at 89% and 100% conveyor speeds, indicating 30 kg ha^{-1} (27 lb ac^{-1}) and 28 kg ha^{-1} (25 lb ac^{-1}) loss reductions, respectively, when compared to the 115% conveyor speed ($p<0.05$). In 2019 under the Apogee grouping, mean total above ground losses were significantly lower (by 85 kg ha^{-1}; 76 lb ac^{-1}) at the 85% conveyor speed as compared to those at the 115% conveyor speed. In 2018 under the standard rod spacing grouping, significant reductions of losses equal to 25 kg ha^{-1} (22 lb ac^{-1}) and 26 kg ha^{-1} (23 lb ac^{-1}) were determined at the 89% and 100% conveyor speeds, respectively, as compared to the 115% conveyor speed. The 100% conveyor speed here also demonstrated significantly lower losses than the 65% conveyor speed.

Testing in 2019 demonstrated recovered yield maximization to consistently occur at the 100% conveyor speed treatments across all comparisons. The 100% conveyor speed increased yield by 289 kg ha^{-1} (258 lb ac^{-1}) as compared to the worst performing treatment, the 85% conveyor speed ($F_{3,71} = 0.9163$, $p = 0.4375$); this equates to a difference in peanut revenue value of \$127 ha^{-1} (\$52 ac^{-1}). Inversion ratings were found to be significantly ($\alpha = 0.05$) improved at the 85%, 100%, and 115% conveyor speed treatments in 2019 when compared to the 70% conveyor speed.

The presented findings suggest that producers may benefit from operating conveyors in a range of 85% to 100% of ground speed, slowing conveyor speeds near 85% in heavy vine load conditions and speeding up conveyors in lighter vine conditions.

It is also indicated that operation of conveyors outside of the 85% to 100% range can result in significant increases in digging losses and significant effects on inversion.

Methods to Monitor Vine Load Conditions

The application of vine speed sensing for indicating conditions favorable to inversion related losses were tested under objective III. A radar ground speed sensor and a high-speed camera were directed at the general area above the inversion assembly to determine if a relationship existed between vine speed there and conditions generally resultant of vine load. Analyses were conducted to determine if there were detectable differences in relative vine speed and relative vine speed ratios (vine speed divided by conveyor speed) as a function of vine load. Indication of significantly different relative vine speeds, or other measures derived from vine speed sensing (vine speed ratios), could allow for differentiation of vine load by the vine speed monitoring systems. Such relationships could potentially be utilized as control mechanisms in the future.

The radar and camera vine speed measurements were found to be significantly (α=0.05) affected by conveyor speed in both years of testing. Both speed measurement methods were able to detect speed differences across most conveyor speed treatments in both years.

Rod spacing treatments which simulated vine load was found to significantly influence measured vine speed (α =0.05). These findings suggest that the speed sensing technology can effectively differentiate the effects of speed due to interactions of vine load with the inverter rod assembly. Although significant differences in vine speeds measured by the camera were not initially detected in camera vine speeds, once additional considerations of conveyor speeds were made significant speed detection occurred.

Vine mass control strategy treatments were found to significantly (α =0.05) affect vine speed when assessed under groupings of conveyor speeds monitored by radar or camera. The indicated effects of vine mass reduction on speed were sometimes minimal. However, effective detection of speed differences in these instances was consistently achieved when conveyor speed was considered. A reduction of speed variability in measurements resulted in significant difference detection. Consideration of conveyor speeds in the analyses was an effective means to address this variability, either through grouping of treatments or of derived speed ratios.

Linear regressions were fitted for monitored camera vine speed as a function of average radar vine speed for the 2018 and 2019 test years. It was found that average radar speed significantly (α=0.05) predicted camera speeds, in 2019 average radar speed explained 48% of measured camera speed variation. Correlations between camera and radar speeds improved from 2018 to 2019, presumably as a result of repositioning and reorienting the radar sensor. General lack of correlation between the vine speed measurements could be due to a number of factors, including: the subjective nature of the camera speed measurements, the discrete nature of the camera measurements (speed of one plant) as compared to radar measurements which were continuously measured over 6 m (20 ft) distance, positioning of the radar, and the variation in the canopy in the area of measurement.

The results of this study addressed the effects of vine load during peanut digging operations. Increases in vine load were found to negatively impact harvest efficiency during digging, supporting previous research. Suggestions of optimal operational digger settings were made to combat the negative effects of excessive vine load. Implementation of these practices are believed, as indicated by these results, to maximize performance during digging operations to reduce peanut digging losses. These suggestions include vine mass reduction such as application of plant growth regulator (e.g., Apogee) or mechanical mowing of vine and optimizing conveyor speeds in a range of 85-100% of ground speed. The potential for implementation of speed sensing technology was found to be favorable in a peanut harvest situation. The amount of variability encountered during peanut digging operations is vast, and further research is needed in a wide range of harvest conditions to better understand the effects of vine load. Additional research is needed to determine methods to incorporate vine speed sensors in peanut harvest. Continued investigation on improved methods to combat vine load during digging operations offer many potential benefits for peanut growers.

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CHAPTER FIVE: SOURCES OF PEANUT DIGGING LOSSES AND STRATEGIES TO REDUCE LOSSES DURING HARVEST CONCLUSIONS

The studies discussed and demonstrated the effects of the peanut digger and various digger components on harvest, digging losses, and digging performance under a range of harvest conditions. The three studies provided a quantification of losses associated with a range of harvest conditions and their interaction with the peanut digger. The findings from these studies can potentially provide producers with a substantial and sometimes significant advantage while digging peanuts. Research to provide improved recommendations for digger setup and operation was and still is needed since current industry recommendations are generally reliant on a relatively small amount of research and believed to be heavily dependent on experience and observation. The three studies conducted sought to address some of the challenges faced by producers. While the studies cannot account for the vast amount of variability across growing seasons, machinery condition and operation, and variables specific and unique to each producer’s harvest situation, the presented findings are believed to describe effects consistently occurring in most harvest situations.

Effect of Peanut Digger Blade Geometry on Yield and Losses Study

The objectives of the blade geometry study investigated the impact of blade geometry and aggression effects on recovered yield blade depth and blade depth stability. The effects of blade geometry were investigated in a range of harvest conditions, including heavy and light soil types, and various disease pressure was imposed by two treatment levels of late leaf spot control (high and low late leaf spot control).

It can be concluded from the study that blade aggression plays a significant role in the recovery of peanut yield under certain harvest conditions. The study provided support that blade geometries with increased aggression positively affect recovered yield during the peanut digging process. Overall, a positive impact of increased blade aggression on recovered yields was indicated by trends within the datasets in the tested harvest conditions. In heavy soil conditions and low leaf spot control treatments, or conceivably the most adverse digging conditions imposed in the study, blade geometry was found to significantly (α=0.10) impact recovered yield. In these conditions, the large shim treatment provided yield benefits of 532 kg ha^{-1} (475 lb ac^{-1}) when compared to the worst performing blade geometry for the conditions (blade bevel up); when compared to the industry-recommended blade bevel down geometry, the large shim geometry increased mean recovered yields by 347 kg ha^{-1} (310 lb ac^{-1}). Considering a peanut value of $441 Mg^{-1} ($400 ton^{-1}), the yield benefits of the large shim geometry comparatively to the blade bevel up and down treatments could respectively provide substantial impacts of $235 ha^{-1} ($95 ac^{-1}) and $153 ha^{-1} ($62 ac^{-1}) in increased revenue through the use of optimized blade geometry.

Based on the findings of the blade geometry study, a positive relationship is further believed to generally exist between blade aggression and recovered yield. Introduction of a hypothesis attributes these improvements to the effects of methods to increased aggression (shimming), which provide greater lifting forces, while achieving better destruction of the soil structure around the plant, thereby reducing the force required to separate the plant (and attached pods) from the soil, reducing losses. Evidence supporting the hypothesis is suggested through the general trends of increased yields seen in this study, an increased degree of soil structure failure is believed to occur due to the increase in blade angle achieved through shimming; another benefit believed to occur is provided by the increased lift to the plant material and is evident with its application of increased blade aggression. These benefits are suggested to be directly evident under the heavy soil and low leaf spot control treatment conditions.

The effects of blade geometry with respect to blade depth was also investigated, and it was confirmed that practices of increasing blade aggression resulted in significantly deeper depths than the traditional factory recommended geometry of blade bevel down. The blade bevel down geometry resulted in significantly shallower digging depths in heavy soils (56.3%) and light soils (56.5%). The large shim resulted in the deepest digging depths in the two soil types (57.8% in heavy soils and 58.8% in light soils). Shallower depths (indicated by lower percentages in this study) while digging are believed to increase the probability of the blade impacting the peanut pod and increase the probability of losses.

Further investigation of blade geometry on blade depth stability concluded that in the two soil types, blade depth stability significantly increased with aggression. Overall, the large shim geometry was the most depth-stable configuration. In heavy soils, the mean blade depth standard deviation for the large shim treatment was 3.04%; in light soils, the mean blade depth standard deviation was 3.91%. The bevel down geometry, when compared to the large shim treatment, resulted in significantly higher mean blade depth percentage standard deviations of 6.65% and 9.00% in the heavy and light soils, respectively. Reduction in blade depth variability, through increasing aggression, is hypothesized to allow operators to maintain target digging depths with better accuracy and reducing the potential for yield loss caused by deviation from optimal digging depths.

It is concluded from the blade geometry study that benefits of increased blade aggression include improved blade depth and stability resulting in improved yield recovery, reduced blade wear, and improved operator control; future evaluation of these effects in the absence of an automated depth control digger is needed.

Effects of Peanut Digger Inversion Assembly on Yield and Losses Study

The objectives of the peanut digger inversion assembly study investigated the effect of the current digger's inversion assembly in a range of harvest conditions. The effect of the inversion assembly on recovered yield and above ground losses was quantified, various harvest conditions were imposed through the implementation of various digger settings, vine load control strategies, various digging ground speeds, and instances of varying levels of disease pressure.

The two years of the disassembly study conclude that in some harvest conditions, peanut harvest losses are significantly affected by the presence of the inversion assembly. It was further found that the performance of the current design of the inversion assembly is optimized within a range of digger settings and crop parameters, indicating limitations of the assembly. Operation outside of these ranges was found to be detrimental during digging processes.

The inversion assembly was found to significantly influence the recovery of yield under the various imposed conditions during peanut digging operations. Increased vine load resulted in a substantial increase in losses due to the inversion assembly. Heavy vine load conditions were imposed in this study; peanuts under these conditions were not treated with Apogee and were dug at 115% conveyor speed settings. Under the heavy vine loads, losses in recovered yields reached 131 kg ha^{-1} (117 lb ac^{-1}) in 2019; these losses were caused by inversion assembly under the aforementioned heavy vine load conditions and corresponded to an impact in revenue of \$58 ha^{-1} (\$23 ac^{-1}). It is recommended that producers avoid or modify digger operation under heavy vine loads and increased conveyor speeds, as suggested by these findings.

In 2019, increased mean above ground losses was associated to the presence of the inversion assembly. Mean above ground losses tended to increase for the treatments where the inversion assembly was installed, and conveyor speeds diverged from the 100% conveyor speed treatment. Despite significance, the tendency for increased above ground losses suggests an optimal operational range of the conveyor speed in respect to the inversion assembly near 100% of ground speed.

Under the reduced vine load following application of Apogee, mean recovered yields generally increased with utilization of the inversion assembly. In heavy vine conditions or where Apogee was not applied, these losses reached 27 kg ha^{-1} (24 lb ac^{-1}), suggestive of a negative relationship between increased vine load and the inversion assembly.

Further, in the 2020 disassembly test at varying ground speeds, the average recovered yield was higher for the inversion assembly removed treatments across the three speed treatments. When ground speed is increased, the feed rate of peanut material is inherently increased, resulting in increased vine loads. At 5.6 kph (3.5 mph) ground speed, where vine load would be expected to be heaviest as a function of ground speed, the lowest numerical recovered yield was obtained. Recovered yield was 105 kg ha^{-1} (94 lb ac^{-1}) lower for treatments where the inversion assembly was installed than where it was removed at a given speed. Additionally, significantly (α=0.05) greater mechanical above ground losses resulted under various ground speeds when the inversion assembly was installed. This suggests a 23 kg ha^{-1} (21 lb ac^{-1}) increase in mechanical losses at 4.0 kph (2.5 mph) in the presence of the installed inversion assembly. These findings showed the potential for inversion assembly to create significant losses even at ground speeds found to be optimal for digging conditions; the results generally indicated increased losses with increases speed in the presence of the inversion assembly, indicating areas where improvements can be made.

Analysis at various levels of disease pressure in 2020 indicated that the inversion assembly negatively affected recovered yield in the presence of high levels of disease pressure and increased ground speeds. Overall, across all levels of late leaf spot control, the inversion assembly removed treatments resulted in 42 kg ha^{-1} (37 lb ac^{-1}) higher average recovered yields.

It is concluded from the two years of the effects of the peanut digger inversion assembly study that the current inversion assembly resulted in increased harvest losses under a range of harvest conditions. Within a range of optimal operation parameters, the losses associated with the inversion assembly are generally minimized. The potential for conditions to deviate during harvest is significant, making optimization of performance crucial for specific situations. Future research is needed to understand the influence of the inversion assembly in a wider range of harvest conditions. Additional research is also suggested, which investigates alternate methods of inversion, to better understand the effects described in this study, as well as to reduce associated losses.

Effects of Vine Load on Digging and Strategies to Address Vine Load

The two-year effects of vine load and strategies to address vine load study demonstrated the effects of vine load on above ground losses and recovered yield during the peanut digging process. The objectives of the study included: objective I which addressed vine load control strategies which reduced vine mass through chemical and mechanical means; objective II investigated vine load control through the adjustment of digger settings (conveyor speeds and inversion rod spacing); an investigation of methods to monitor vine load for potential indication of vine load control (application of speed sensing) was tested under objective III. The objectives quantified recovered yield and digging losses as functions of vine load control treatments, digger treatments, and the evaluation of the application of vine speed sensing for indicating conditions favorable to inversion related losses.

Strategies to reduce vine load under objective I and objective II, in some cases significantly reduced losses during digging and increased recovered yields. It was further concluded from these results that the methods of radar vine speed sensing and camera vine speed sensing, tested to monitor vine load for the potential indication of vine load control, could be beneficial to peanut digging processes.

Vine Mass Control Strategies

Objective I was examined in the 2018 and 2019 vine mass control strategies studies. Three vine mass control strategies were employed to manipulate vine load prior to digging through chemical and mechanical means, in addition to an untreated check. The two methods of vine mass reduction included the application of the plant growth regulator Apogee (prohexadione calcium) and mechanical mowing of vines with a rotary mower; the untreated check did not encompass any vine mass reduction strategies.

The vine mass control strategies study concluded that vine load as a function of plant vine mass control significantly affects the magnitude of above ground losses, recovered peanut yields, and inversion ratings. A reduction in above ground losses, increase in yield recovery, and improvements in inversion accompanied utilization of vine mass reduction strategies.

Total above ground losses were found to be significantly reduced (α=0.10) by mechanical mowing. Mechanical mowing reduced total above ground losses when compared to the untreated check by 9 kg ha^{-1} (8 lb ac^{-1}). Further, a general positive impact of lower mean above ground mechanical losses was demonstrated with the application of Apogee when compared to the untreated check.

In addition, statistically (α=0.10) improved recovered yields of 275 kg ha^{-1} (245 lb ac^{-1}) were found with the use of Apogee vine mass control treatments over the untreated check. Considering a peanut value of \$441 Mg^{-1} (\$400 ton^{-1}), an estimated revenue increase of \$121 ha^{-1} (\$49 ac^{-1}) was associated with the yield increased when Apogee vine mass control treatments were applied. Further, mowing numerically increased recovered yields compared to the untreated check by 161 kg ha^{-1} (143 lb ac^{-1}), corresponding to an estimated revenue increase of \$71 ha^{-1} (\$29 ac^{-1}).

Inversion ratings were significantly (α=0.05) improved by the application of Apogee in 2019. A 4.1% improvement in inversion ratings was associated with the application of Apogee when compared to mowing.

Although Apogee treatments were demonstrated to increase yield and revenue, profitability would likely decrease due to the application cost associated with Apogee. The cost of Apogee application is estimated at \$166 ha^{-1} (\$67 ac^{-1}) for two three-quarter label rate applications, similar to those used in this study. Further research is needed to determine the economic impact of vine mass reduction techniques in various harvest conditions.

Mechanical Vine Load Control Strategies

Objective II investigated the effects of mechanical vine load control strategies on digging losses, recovered peanut yield, and inversion ratings. Three inversion rod spacing treatments and five conveyor speed settings, relative to a ground speed of 4.0 kph (2.5 mph) were used in 2018. Four conveyor speed settings relative to a ground speed of 3.2 kph (2 mph) were investigated in 2019.

Mechanical vine load control strategies significantly influenced peanut digging operations. Digger performance was optimized under a range of mechanical vine load control strategies where above ground losses were reduced while recovered yields and inversion ratings were improved.

Rod spacing was optimized at the standard rod spacing, resulting in the best performance generally across treatments. Narrow rod spacing significantly ($\alpha=0.05$) increased total above ground losses by 17 kg ha^{-1} (15 lb ac^{-1}) to 25 kg ha^{-1} (22 lb ac^{-1}) when compared to standard and wide rod spacing, respectively.

Significant ($\alpha=0.05$) reductions of total above ground losses were indicated across treatments when standard rod spacing was compared to narrow rod spacing treatments under Apogee vine mass control strategies, a difference of 39 kg ha^{-1} (35 lb ac^{-1}). Under the untreated check vine mass control strategy, narrow rod spacing significantly ($\alpha=0.05$) increased total above ground losses compared to standard rod treatments (22 kg ha^{-1} [20 lb ac^{-1}]). Comparison of rod spacing treatments (narrow compared to standard) under the mowed vine mass control resulted in additional significant differences ($\alpha=0.10$) of 18 kg ha^{-1} (16 lb ac^{-1}). This suggests optimization of performance at the standard rod spacing. Additional research is needed which includes various makes and models of diggers while implementing a wider range of harvest situations.

The mechanical vine load control strategies study also investigated various conveyor speeds settings. Conveyor speed settings significantly influenced above ground losses, recovered peanut yields, and inversion ratings. Conveyor speed setting adjustments were determined to effectively optimize digging operations in a range of vine conditions imposed under Objective I. The study demonstrated that conveyor speeds were generally optimized in the 85% to 100% of ground speed range across all imposed harvest conditions in respect to above ground losses, yield recovery, and inversion ratings.

Total above ground losses were found to be minimized at conveyor speeds of 89% and 85% of ground speeds in 2018 and 2019 respectively. In the 2018 mechanical vine load control strategy study the 89% and 100% conveyor speed control treatments significantly (α=0.05) reduced losses compared to the 65% and 115% conveyor speed treatments. Total above ground losses were found to be reduced as much as 18 kg ha^{-1} (17 lb ac^{-1}) when conveyor speeds were set to 89% of ground speed and as much as 15 kg ha^{-1} (13 lb ac^{-1}) at the 100% conveyor speed settings.

In 2019, the 85% conveyor speed treatments were associated with 30 kg ha^{-1} (27 lb ac^{-1}) significantly (α=0.05) less total above ground losses. These findings suggest that overall total above ground losses are significantly minimized in a conveyor speed range of 85% to 100% of ground speed.

Treatments under the Apogee vine treatment in 2018 were found to be significantly (α=0.05) affected by conveyor speed settings. The lowest mean total above ground losses were reported at the 89% and 100% conveyor speed settings. Improved total above ground losses of 30 kg ha^{-1} (27 lb ac^{-1}) and 28 kg ha^{-1} (25 lb ac^{-1}) were found at the 89% and the 100% conveyor speed settings, respectively, in plots treated with Apogee. Similarly, in 2019, mean total above ground losses under the Apogee vine mass control strategy were significantly (α=0.05) lower at the 85% conveyor speed treatments (85 kg ha^{-1}; 76 lb ac^{-1}). Conveyor speed settings of 85% to 100% were consistently associated with minimized total above ground losses in the presence of variable vine load.

The effects of conveyor speed treatment by rod spacing significantly (α=0.05) impacted total above ground losses in 2018. Losses were reduced by 26 kg ha^{-1} (23 lb ac^{-1}) at optimal conveyor speeds of 100%, under standard rod spacing. Mean total above ground losses were generally higher under the narrow rod treatments compared to other rod treatments at all conveyor speeds. Narrow rod spacing is believed to simulate the rod interaction under heavy vine loads and suggest a negative interaction between vine load and its relationship to conveyor speed setting and rod spacing.

In 2019, the overall optimal conveyor speed for maximized recovered yields was determined. Recovered yield maximization occurred at the 100% conveyor speed treatments. Mean recovered yield differences, although not significant, of 289 kg ha^{-1} (258 lb ac^{-1}) were found between the 100% conveyor speed treatment when compared to the 85% conveyor speed treatment. Estimates of the revenue differences influenced by the yield differences suggested a value of \$127 ha^{-1} (\$52 ac^{-1}) in recovered yield between the two mentioned conveyor treatments. This suggests conveyor speed settings may have substantial impact on harvest revenue.

Inversion was influenced by conveyor speed in 2019. A significant (α = 0.05) improvement in inversion ratings was found at the 85%, 100%, and 115% conveyor speed treatments when compared to the 70% conveyor speed. At the 100% conveyor speed treatment, inversion ratings were minimized, although the 85% and 115%

conveyor speed settings were not statistically different than the 100% conveyor speed treatment.

The findings of this study suggest production benefits from conveyor operation at 85% to 100% of ground speed. The findings suggest slowing conveyor speeds near 85% in heavy vine load conditions and speeding up conveyors to 100% in reduced vine load conditions. Adjustment of conveyor speed in the 85% to 100% range were concluded to effectively combat harvest losses associated with vine load.

Methods to Monitor Vine Load Conditions

Under objective III, methods of vine speed sensing were tested. A Dickey-john Radar II ground sensor and a high-speed camera were installed on the digger to investigate if a relationship between measured vine speed and conditions conducive to losses could be identified within the digger. The speed sensing technology was directed at the general area above the inversion assembly to determine if a relationship existed between vine speed and vine load conditions. Detectable differences in relative vine speed and relative vine speed ratios as a function of vine load were indicated; significant detection ability could allow for the potential differentiation of vine load by the vine speed monitoring systems. Therefore, there is potential for speed detection to be utilized as a mechanism for automated vine load control in the future.

The two studied methods of speed monitoring were found to significantly (α=0.05) detect speed differences across conveyor speed treatments in both years of the study. Further, rod spacing treatments were imposed to simulated vine load conditions in the study. Measured speed was found to be significantly influenced by the treatments (α =0.05). Vine mass control treatments significantly (α =0.05) affected vine speed when assessed under groupings of conveyor speeds monitored under the radar or camera speed measurement methods. Application of a speed ratio was also found to be an effective metric of detection, providing additional benefits to those of vine speed alone. The indicated effects of vine mass reduction on speed were sometimes found to be minimal. However, effective detection of speed differences in these instances was consistently achieved when conveyor speed was considered. These findings suggest that the speed sensing technology can effectively differentiate the various magnitudes of differences in speed due to a large range of interactions of vine load and conditions within the digger.

Linear regressions were fitted for monitored camera vine speed as a function of average radar vine speed for the 2018 and 2019 test years. Models significantly predicted camera speed and explained of 48% of measured camera speed variation when radar position was optimized in the study. A number of factors are believed to influence the correlation between measurements, although improvement through repositioning was indicated. This correlation was suggested to be affected by several factors including: the subjective nature of the camera speed measurements, the discrete nature of the camera measurements as compared to methodology of radar measurements, positioning of the radar, and the variation in the crop canopy within the area of measurement.

The potential for implementation of speed sensing technology was found to be favorable in a peanut harvest situation. However, the amount of variability encountered during peanut digging is vast and further research is needed in a wide range of harvest conditions to better understand the application methods to monitor vine load. Additional research is needed to determine the relationship of vine speed sensors on peanut harvest. Improvements to peanut harvest and advancements in the current methods of the peanut inversion offer the potential for substantial positive impacts in the peanut industry.

Closing Remarks

Further investigation is needed to better understand the relationships between the current peanut digger and harvest. Generally, under optimal harvest conditions, harvest efficiency is maximized. However, the limitations of the digger have not currently been widely researched. Through an improved understanding of the performance of digging operations, improved harvest efficiencies have been shown to be resultant in these studies and their like. More research is needed to better define the interaction of digger blade geometry, the inversion assembly, and effects of vine load and strategies to address it with respect to peanut harvest losses. Future research in a wider range of harvest conditions, digger makes and models, and operational methods could benefit the research presented here and the peanut industry alike. The limited availability of such research indicates an area of need. The findings of future studies are likely to provide producers with a better understanding of harvest limiting factors, such as those encountered while digging, and provide producers with a substantial and sometimes significant advantage while digging peanuts.

APPENDICES

Appendix A

SOURCES OF PEANUT DIGGING LOSSES AND STRATEGIES TO REDUCE LOSSES DURING HARVEST

Table A1. Mean recovered peanut dry yield (kg ha^{-1}) as a function of disassembly for the 70% conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment ($F_{1,11}$ = 0.1032, p= 0.7541)				Untreated Check vine treatment $F_{1,12}$ =0.2069, p= 0.6573			
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	7	2900	A	520.9	7	2803	A	418.9
Removed	6	2654	A	562.6	7	2534	A	418.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A2. Mean recovered peanut dry yield (kg ha^{-1}) as a function of disassembly for the 100% conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment ($F_{1,11}$ = 0.0192, p= 0.8922)				Untreated Check vine treatment ($F_{1,11}$ = 0.1093, p= 0.7471)			
Inversion Assembly Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	7	2892	A	514.1	7	3009	A	360.2
Removed	6	2787	A	555.2	6	2833	A	389.1

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A3. Mean recovered peanut dry yield (kg ha^{-1}) as a function of vine load treatment in the 2019 test year. ($F_{1,74}$ = 0.3987, p= 0.5297)

Vine Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Apogee	24	3007	A	198.6
Untreated Check	52	2920	A	134.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A4. Mean recovered peanut dry yield (kg ha^{-1}) as a function of conveyor speeds in the 2019 test year. (F$_{2,72}$ = 0.4758, p= 0.7001)

Conveyor Speed Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	25	2893	A	195.4
85%	14	2715	A	261.1
100%	24	3083	A	199.4
115%	14	3053	A	271.0

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A5. Mean recovered peanut dry yield (kg ha^{-1}) as a function of conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment (F$_{1,24}$ = 0.0122, p= 0.9129)				Untreated Check vine treatment (F$_{3,50}$ = 0.4591, p= 0.7121)			
Conveyor Speed Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	13	2787	A	364.6	14	2669	A	264.1
85%	-	-	-	-	14	2715	A	264.1
100%	13	2844	A	364.6	13	2928	A	274.1
115%	-	-	-	-	13	3053	A	274.1

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A6. Mean recovered peanut dry yield (kg ha^{-1}) as a function of ground speeds in the 2020 test year. (F$_{2,86}$ = 0.8596, p= 0.4269)

Ground Speed Treatment	N	Mean Recovered Yield (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
2.4 kph	30	3248	A	194.6
4.0 kph	29	2995	A	198.0
5.6 kph	30	2899	A	194.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A7. Above ground losses (kg ha^{-1}) as a function of disassembly for the 70% conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment (F$_{1,12}$ = 0.467, p= 0.5074)				Untreated Check vine treatment (F$_{1,12}$ = 0.55, p= 0.4726)			
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	7	102	A	19.4	7	90	A	15.0
Removed	7	83	A	19.4	7	75	A	15.0

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A8. Above ground losses (kg ha^{-1}) as a function of disassembly for the 100% conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment ($F_{1,12}$ = 0.1305, p= 0.7242)				Untreated Check vine treatment ($F_{1,12}$ =0.0378, p= 0.8491)			
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Installed	7	103	A	17.4	7	72	A	13.6
Removed	7	94	A	17.4	7	76	A	13.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A9. Above ground losses (kg ha^{-1}) as a function of vine load treatment in the 2019 test year. ($F_{1,82}$ = 1.8297, p= 0.1799)

Vine Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Apogee	28	95	A	7.2
Untreated Check	56	83	A	5.1

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A10. Above ground losses (kg ha^{-1}) as a function of conveyor speed treatment in the 2019 test year ($F_{3,80}$ = 0.0224, p= 0.9954).

Conveyor Speed Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	28	88	A	7.4
85%	14	89	A	10.4
100%	28	86	A	7.4
115%	14	88	A	10.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A11. Above ground losses (kg ha^{-1}) as a function of conveyor speeds under vine load treatment in the 2019 test year.

	Apogee vine treatment ($F_{1,26}$ = 0.0916, p= 0.7646)				Untreated Check vine treatment ($F_{3,52}$ = 0.5958, p= 0.6206)			
Conveyor Speed Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[b]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
70%	13	93	A	13.0	14	82	A	9.0
85%	-	-	-	-	14	89	A	9.0
100%	13	98	A	13.0	13	74	A	9.0
115%	-	-	-	-	13	88	A	9.0

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A12. Aboveground losses (kg ha^{-1}) as a function of disassembly for the three levels of late leaf spot control in the 2020 test year.

	High level late leaf spot control treatment			Medium level late leaf spot control treatment			Low level late leaf spot control treatment		
	($F_{1,27} = 0.2718$, p= 0.6064)			($F_{1,27} = 0.9828$, p= 0.3303)			($F_{1,27} = 0.0001$, p= 0.9928)		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	15	670A	55.5	15	775A	57.0	15	1035A	57.7
Removed	14	712A	57.5	14	831A	59.0	14	1036A	59.7

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A13. Aboveground losses (kg ha^{-1}) as a function of disassembly at the low level of late leaf spot control in the 2020 test year.

	2.4 kph speed treatment			4.0 kph speed treatment			5.6 kph speed treatment		
	($F_{1,8} = 0.015$, p= 0.9057)			($F_{1,8} = 1.8657$, p= 0.2091)			($F_{1,8} = 0.0125$, p= 0.9137)		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	1055A	157.9	5	943A	49.1	5	1106A	103.4
Removed	5	1083A	157.9	5	1038A	49.1	5	1190A	103.4

[a] Treatments with the same letter indicate no significant differences (student's t-test, α=0.05).

Table A14. Aboveground losses (kg ha^{-1}) as a function of disassembly at the medium level of late leaf spot control in the 2020 test year.

	2.4 kph speed treatment			4.0 kph speed treatment			5.6 kph speed treatment		
	($F_{1,7} = 0.0379$, p= 0.8512)			($F_{1,8} = 1.5424$, p= 0.2494)			($F_{1,7} = 1.8839$, p= 0.2123)		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	730A	124.5	5	810A	74.7	5	786A	61.9
Removed	4	754A	139.2	5	941A	74.7	4	907A	69.2

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A15. Aboveground losses (kg ha^{-1}) as a function of disassembly at the high level of late leaf spot control in the 2020 test year.

	2.4 kph speed treatment ($F_{1,8}$ = 0.2664, p= 0.6197)			4.0 kph speed treatment ($F_{1,7}$ = 0.0537, p= 0.8234)			5.6 kph speed treatment ($F_{1,8}$ = 0.0186, p= 0.8949)		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	641A	87.5	5	662A	102.0	5	707A	118.9
Removed	5	705A	87.5	4	698A	114.0	5	730A	118.9

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A16. Aboveground losses (kg ha^{-1}) as a function of the three levels of late leaf spot control in the 2020 test year. ($F_{2,83}$ =17.6378, p <.0001)

Late Leaf Spot Control Level Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Low	28	1018	A	40.0
Medium	29	802	B	39.3
High	29	690	C	39.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A17. Aboveground losses (kg ha^{-1}) as a function of ground speeds in the 2020 test year. ($F_{2,83}$ =1.0176, p=0.3659)

Ground Speed Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
2.4 kph	27	779	A	48.0
4.0 kph	29	854	A	46.3
5.6 kph	30	867	A	45.6

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A18. Aboveground mechanical losses (kg ha^{-1}) as a function of disassembly at the medium level of late leaf spot control in the 2020 test year.

	2.4 kph speed treatment ($F_{1,7}$ = 2.6107, p= 0.1502)			4.0 kph speed treatment ($F_{1,8}$ = 0.7242, p= 0.4195)			5.6 kph speed treatment ($F_{1,8}$ = 0.0815, p= 0.7825)		
Inversion Assembly Treatment	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})	N	Mean Total Above Ground Losses (kg ha^{-1}) [a]	SE (kg ha^{-1})
Installed	5	62A	12.3	5	34A	7.7	5	73A	20.8
Removed	4	32A	13.7	5	25A	7.7	5	65A	20.8

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A19. Above ground mechanical losses (kg ha^{-1}) as a function of the three levels of late leaf spot control in the 2020 test year. ($F_{2,85}$=2.4632, p=0.0912)

Late Leaf Spot Control Level Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
Low	30	58	AB	6.5
Medium	29	49	B	6.5
High	29	64	A	6.5

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table A20. Above ground mechanical losses (kg ha^{-1}) as a function of ground speeds in the 2020 test year. ($F_{2,85}$=6.0392, p=0.0035)

Ground Speed Treatment	N	Mean Total Above Ground Losses (kg ha^{-1})	T-Test Grouping[a]	SE (kg ha^{-1})
2.4 kph	29	57	A	6.4
4.0 kph	29	44	B	6.4
5.6 kph	30	70	A	6.3

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Appendix B

The Effects of Vine Load and Strategies to Reduce Vine load

Table 3.1B. Mean recovered peanut dry yield (kg ha^{-1}) as a function vine mass control strategy treatment for varying conveyor speeds in the 2019 test year.

	70% Conveyor speed treatment[b] $F_{2,15}$ = 0.4403, p= 0.6519			85% Conveyor speed treatment $F_{2,15}$ = 0.5195, p= 0.5722			100% Conveyor speed treatment $F_{2,15}$ = 0.2159, p= 0.8083			115% Conveyor speed treatment $F_{2,17}$ = 0.4817, p= 0.6259		
Treatment	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (%)	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (%)	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (%)	N	Mean Recovered Yield (kg ha^{-1}) [a]	SE (%)
Apogee Vine Treatment	7	3669A	166.4	6	3548A	210.4	5	3825A	307.1	7	3703A	239.3
Untreated Check Vine Treatment	6	3447A	179.7	7	3239A	194.8	6	3552A	280.3	7	3414A	239.3
Mowed Vine Treatment	5	3511A	196.9	5	3375A	230.5	7	3658A	259.5	6	3409A	258.4

[a] Treatments with the same letter indicate no significant differences (α=0.05).

Table 3.2A. Mean radar speed vs. conveyor ratio as a function of rod spacing treatments in the 2018 test year. [a]

Rod Spacing Treatment	N	Mean Speed Ratio	SE
Standard	45	1.8	0.03
Wide	22	1.7	0.05

[a] Unable to normalize (W=0.948241, p= 0.0077).

Table 3.3A. Mean radar speed vs. conveyor ratio as a function of three vine mass treatments in the 2018 test year.[a]

Vine Mass Control Treatment	N	Mean Radar Speed Ratio	SE
Apogee Vine Treatment	24	0.8	0.03
Untreated Check Vine Treatment	21	0.8	0.03
Mowed Vine Treatment	24	0.8	0.03

[a] Unable to normalize (W=0.948241, p= 0.0077).