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Is row-unit vibration affected by planter speeds and downforce? What are the effects?

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Abstract.

Planter's row-unit vibration can possibly interfere on seed metering and delivery process, affecting crop emergence and final stand. In this way, setting proper speeds, and using planter`s downforce to decrease vibration are good strategies to keep planting uniformity. This study aimed to verify if there are differences on row-unit vibration variability and peanuts plant spacing when planting is performed using different displacement speeds and downforces. Also, to verify if there is correlation between the vibration, downforce and other variables as seeding depth, seedling emergence, plant spacing, and peanuts yield. The test was performed at the Gulf Coast Research and Extension Center in Fairhope, AL, USA. A 4 row John Deere Max Emerge XP Planter with 97 cm of row spacing was set to plant peanuts at 6.3 cm. A commercial hydraulic downforce system was used. The hydraulic downforce system can be used in two operational modes: Dynamic or Static. The dynamic control the loads according to soil variability, using down or uplift forces. The static applies the loads in a fixed way, not considering soil variability. Treatments were 3 planter speeds (4.8, 6.4, and 8 kilometers per hour (Km/h)), and 6 downforce loads 445, 665, 755, and 870 Newtons (N) using the dynamic mode, and 445 and 870 N using the static mode. The design was a random complete block with three replications for each treatment. Analysis of variance was performed, and when significant, Tukey test also. Linear regression analysis, and Pearson correlation were also performed. The vibration deviation was higher at 6.4 and 8 Km/h. Variability on vibration was also higher when using 444 Newtons compared to 665 or 775 N. There was reduction of the vibration variability when increasing the downforce at 8 Km/h. The coefficient of determination (R^2) was 0.49, meaning that 49% of the vibration reduction was explained by the downforce. In general, increasing the downforce at higher speeds decreased the row-unit vibration variability. Positive association (Pearson correlation) was found between speed and vibration, meaning that when speed is increased, vibration is incremented. Negative association between vibration and emergence velocity was found using the static mode.

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Keywords.
Downward forces, planting, plant spacing

Introduction

Peanut crop (Arachis hypogaea L.) has great economic importance in the world agricultural scenario. In terms of production, China, India, Nigeria, and United States are the biggest producers. In the United States, 650.000 hectares were planted with peanuts in the 2020/2021 season, and the production was close to 2.79 million of metric tons (MT). The production represented approximately 4.29 MT per hectare (USDA, 2022). In 2011, the US production average was approximately 3.70 MT per hectare (USDA, 2012). There was an increasement on the production of 14% in the past 10 years. The increasement on peanuts production was possible due to the technological advances on seeds, machinery, and equipment for planting and harvesting operations, as well as improved production practices. In this way, the continuous investment on planting and harvesting technologies are directly connected to crop production increasement.

Lately, there was an expressive interest on the improvement and usage of planting technologies since the planting operation is one of the most important mechanized processes of the crops production cycle. Virk et al. (2021) also mention the sowing process as the most critical. A mechanized planting process consists of opening a channel (furrow) on the soil to place the seeds at a pre-set depth and close the furrow providing adequate contact from the seeds with the soil for uniform seedling emergence (Morrison 1989). The row-units are the main components of a planter. These units are responsible for opening the furrow at a determined depth, meter and drive the seeds to the furrow and close the furrow. Before planting it is very important to set the row-units to provide good seed-to-soil contact, and good environment for the seeds, which means to issue uniform heat, moisture, and oxygen to the seeds (Ortolani et al. 1996). One key factor for providing a good environment for the seeds, is the seeding depth (Grotta et al. 2008). In this way, to reach a determined and/or required seeding depth is important for the seed germination and crop emergence. For peanut production, seeding depths from 4 to 8 cm provide higher germination percentage, and better emergence velocity (Machado Neto and Pitelli, 1988). Seeding uniformity is also beneficial for crop emergence because the moisture and temperature are more uniform at certain in-furrow layers (Nemergut et al. 2021). In this way, planter's row-unit components interaction with the soil can potentially affect seeding depth, seedling emergence, and initial growth of a determined crop.

The soil reaction force for the opening disks and gauge-wheels is one of the main factors leading to seeding depth variability, and shallow planting. Several authors reported benefitable impacts on seeding depth, and depth uniformity by testing the application of different vertical loads on the row-units to break the soil resistance to penetration (Hanna et al. 2010, Badua et al. 2021; Karayel and Šarauskis. 2011; Oliveira et al. 2021; Virk et al. 2020). The increasement of vertical loads on the row-units is usually done by a system most known as downforce. Different downforce systems are available on the market, and the most used ones are the mechanical (uncompressible springs), pneumatic (airbags), and hydraulic (hydraulic cylinders). Among the commercial products, the hydraulic downforce system stands out because the operator could change loads in real time, using the on-board computer. By using the hydraulic system is possible to choose between dynamic and static downforce operational modes, and select the vertical loads needed for under specific planting conditions. The dynamic mode uses uplift or downforce to keep a target load independent of soil mechanical resistance variability, meanwhile the static mode operates on a fixed force, not considering soil variability. Badua et al. (2018) evaluating different applied loads by a hydraulic fixed downforce mechanism, concluded that there is a need for using an automatic control to get a uniform load distribution on different ground conditions. The importance of the downforce system for reducing row-unit vibration was also documented by Badua et al. (2021), the authors verified that when the downforce is increased, the row-unit vibration is decreased using a dynamic hydraulic downforce system.

Although planter downforce is a key element for planter performance, other factors as planter speeds have been documented as an important parameter that influences row-unit vibration, decreases the amount of applied downforce, and increase downforce variability (Badua et al. 2021; Strasser, 2017). Seed distribution and seedlings emergence are also affected by planting speeds. Mello et al. (2007) documented that the percentage of normal spacing between the plants, plant population, and grains dry mass were decreased when planting corn at 9.8 Km/h. Seed longitudinal distribution was also affected by speeds over 7 Km/h (Melo et al. 2013).

Despite the fact of some studies have already reported the use of different displacement speeds and manual downforces, and the impacts on row-unit vibration and corn planting, there is still a need to verify these impacts on other crops and using different planting speeds and different downforce loads. Therefore, this study aimed to verify if there are differences on row-unit vibration variability and peanuts plant spacing when planting is performed using different displacement speeds and downforces. Also, to verify if there is correlation between the vibration, downforce and other variables as seeding depth, seedling emergence, plant spacing, and peanuts yield

Material and Methods

A field trial to test the vibration of planter row-units using different planter speeds and downforces, and to verify possible impacts on peanuts emergence, plant spacing, and yields was conducted on May 26, 2021. The experiment was performed at the Gulf Coast Research and Extension Center, in Fairhope, AL, USA, near the 30° 32' 09" N, 87° 52' 46" W coordinates. The soil of the field is a Marlboro Very Fine Sandy Loam. The Georgia-06G Peanuts variety was sown at 6.3 cm under strip-till conditions. The plant population was 90.000 seeds per acre, approximately.

For the planting operation a John Deere 6155R 4x2 FWD tractor (John Deere, Moline, IL, USA) and a 4 row John Deere planter (John Deere, Moline, IL, USA) equipped with Max Emerge XP row units were used. The row spacing was 97 cm. The set was guided using a Trimble autopilot system (Trimble, Sunnyvale, CA, USA) using real-time kinematic (RTK) correction signal. The planter was equipped with a commercial hydraulic downforce system Delta Force® (Precision Planting, Tremont, IL, USA) on each row unit. The Delta Force® system allow the operator to control the loads from inside of the cabin, and select different operational modes, as an auto (dynamic) or manual (static). The dynamic mode allows the system to regulate itself using down or uplift force to keep a target downward force taking in consideration the soil variability, meanwhile, the static mode applies a fixed amount force, not considering the variability present on the soils. A 20|20 Monitor 3rd generation display (Precision Planting, Tremont, IL, USA) in the tractor cabin was used to set the different loads and downforce modes, as well as to monitor the sowing operation. The test was planted at average speeds of 4.8, 5.4, and 8.0 Km/h. The downward forces deriving from the system and applied to the depth gauge-wheels were monitored by using the precision planting load pins (Precision Planting, Tremont, IL, USA). The load pins (load cells) were installed in the depth control mechanism. The seed metering mechanism and the seed driving tubes used, were vDrive and BullsEye (Precision Planting, Tremont, IL, USA), respectively. Depth control was managed using the Smart Depth system (Precision Planting, Tremont, IL, USA), in the fixed mode.

The maximum downward force values of the Delta Force® hydraulic system are 870 Newtons (N) for the dynamic mode and 2800 N for the static mode. Downward forces of 0, 550, 1100 and 1800 N are frequently used by producers due to traditional settings of mechanical commercial systems that use springs (Poncet et al. 2018). Taking in consideration the maximum values, as well as the forces commonly used by the producers, different levels of vertical loads, combined with different planter displacement speeds were selected as treatments (Table 1).

Table 1. List and descriptions of the treatments evaluated

Downforce Mode	Treatment number	Treatment description/abbreviation	Downforce Level (N)	Travel Speed (Km/h)
Dynamic (D)	1	Low / LW-D	444	4.8
	2	Low / LW-D	444	6.4
	3	Low / LW-D	444	8
	4	Medium / MED-D	665	4.8
	5	Medium / MED-D	665	6.4
	6	Medium / MED-D	665	8
	7	Medium/High MED/HG-D	755	4.8
	8	Medium/High MED/HG-D	755	6.4
	9	Medium/High MED/HG-D	755	8
	10	High / HG-D	870	4.8
	11	High / HG-D	870	6.4
	12	High / HG-D	870	8
Static (S)	13	Low / LW-S	444	4.8
	14	Low / LW-S	444	6.4
	15	Low / LW-S	444	8
	16	High / HG-S	870	4.8
	17	High / HG-S	870	6.4
	18	High / HG-S	870	8

N: Newtons; Km/h: Kilometers per hour.

Planter speeds were controlled by the operator in the cabin. A buffer zone of 30 meters approximately was created for speed gain/stabilization and maneuvers (Figure 1).

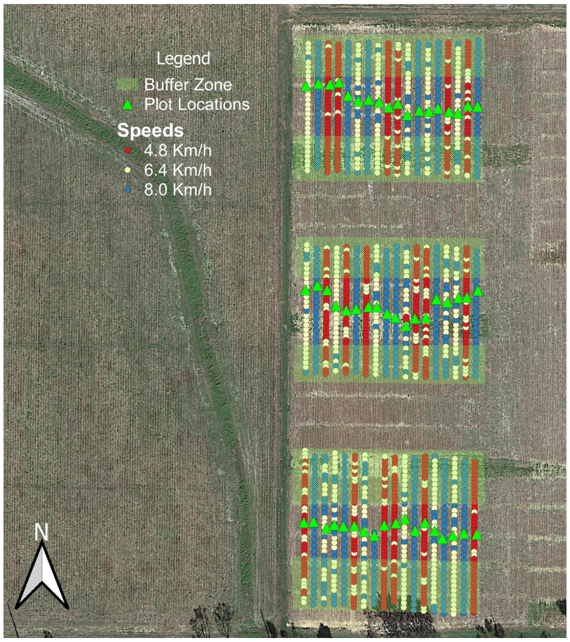

Figure 1. Plot locations and buffer zones for speeds and maneuvers.

The row-unit vibration was assessed by using commercial 0.05° accuracy 6-axis accelerometers, with Kalman Filter and 100 Hz data logger (Wit-Motion, Shenzen, Guagdong Province, CN). Each accelerometer recorded 10 gravity (g) measurements per second. The data was collected using a computer inside of the cabin for each treatment. The accelerometers were installed on two of the four row-units (Figure 2).

Figure 2: Accelerometers installed on the planter. The red circle indicates the location where the accelerometers were installed.

To compare the vibration between the treatments, and to verify the correlation between the vibration and the other variables, the standard deviation of the acceleration (Vibration S.D.) data was calculated and used as the representing variable for row-unit vibration.

Seeding depth was evaluated one day after planting by opening a one-meter length furrow. Using a graduated ruler (Westcott, Seneca, New York, USA), the distance between the bottom of the seed and the soil surface was measured. Approximately 30 seeding depth measurements were performed per treatment on each field.

Seedling emergence was assessed by the emergence velocity index (EVI) proposed by Maguire (1962) and calculated according to the equation (1).

$$\text{EVI: } \frac{E_1}{N_1} + \frac{E_2}{N_2} + \cdots + \frac{E_n}{N_n} \qquad (1)$$

Where:

EVI = Emergence Velocity Index.

E1, E2, En = Number of normal plants counted in the first, second and last evaluation respectively.

N1, N2, Nn = Number of days from planting for first, second and last evaluation respectively.

For the EVI assessment, plants were counted daily inside of each plot for each replication. The counting started when the first seedling emerged and stopped when the number of emerged plants in the day was less than 1% of the previous day.

Plant spacing was assessed 40 days after planting by measuring the space between the plants in a 3-meter row inside of the plot. Peanuts yield was assessed on November 1, 2021, by harvesting 10-meter rows of each treatment.

The experimental design was based on a randomized complete block with 3 replications for each treatment. A total of 18 treatments were tested, resulting in 54 plots. Each plot consisted of approximately 8m^2, represented by 3 m length (Krall et al. 1977) of three rows of the machine.

Analysis of variance (ANOVA) was performed using the statistical analysis software (SAS Institute, Cary, NC, US). When significant, means were separated using the MEANS procedure at 95% significance level. Linear and multiple linear regressions were conducted at the significance level of 95% using the GLM procedure. Pearson correlation heat maps to compare the association between the variables were also performed.

For better understanding, the results were discussed taking in consideration the two downforce modes. The applied downforce for both modes is discussed first, the discussion of all the treatments and variables on the dynamic mode is discussed in second, followed by the static downforce discussion.

Results and Discussion

Planter downforce output (Figure 3) shows that in general, the dynamic mode applied the loads closer to the target when compared to the static mode. The large deviation between the "as applied load" with respect to the target load on static mode can be explained by the soil reaction force to the opening disks and gauge-wheels. As the target seeding depth for peanuts planting is considered deep (6.3 cm), the soil reaction force on the row unit increases, pushing the disks and gauge-wheels out. The under-application of the loads could happen because the static mode applies a fixed amount of downforce, and do not change the loads when needed, as the dynamic mode does. Similar results were found by Badua et al. (2018), in which the authors found that by increasing the seeding depth in 1.25 cm, the gauge-wheel load (downforce) was significantly reduced.

The "as applied" load variability was lower on the dynamic mode compared to the static mode. The final "as applied" load decreased as the planting speed increased and no differences were observed on the planting modes. Using the dynamic mode at 4.8 Km/h, the downforce variability was smaller compared to the other planting speeds (Figure 3). Strasser (2017), simulating the downforce variability at three different speeds (7.4, 9.7, and 12 Km/h), found that when traveling at higher speeds, 12 Km/h, the loads were more uniform and closer to the target. The findings from our studies did not agree with Strasser (2017), probably because the different downforces evaluated on this study as well as soil texture.

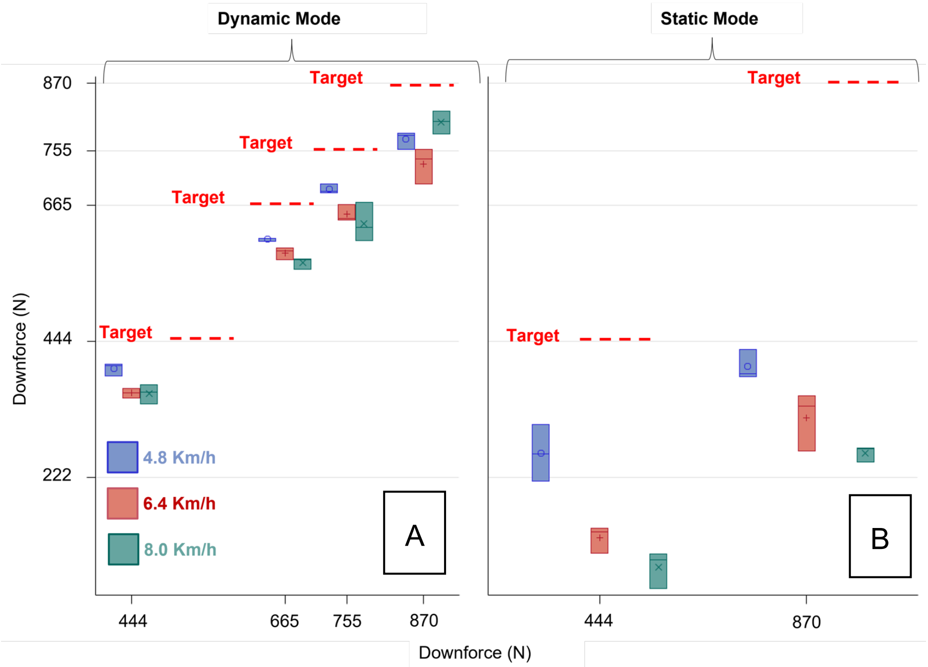

Figure 3. Differences between prescribed (X-axis) and applied (Y-axis) downforce with respect to three plater speeds and two downforce systems. Note: A. Dynamic downforce; B. Static downforce.

Dynamic Downforce

The analysis of variance for the variables collected when the dynamic mode was used are shown on Table 2. There were significant differences of the vibration standard deviation (Vibration S.D.) with respect to planting speeds, downforce, and interaction between speeds and downforce. Seeding depth was impacted by the three levels of downforce tested. No differences were found on the emergence velocity index (EVI), plant spacing, and yield with respect to planting speed, downforce, or the interaction.

Table 2: Analysis of variance (ANOVA) for Vibration S.D., seeding depth, plant spacing, and yield submitted to dynamic mode loads

	Vibration S.D.		Seeding Depth		EVI		Plant Spacing		Yield	
Source of Variation	F	P	F	P	F	P	F	P	F	P
Speed	23.81	<.001	1.09	0.35	2.40	0.11	2.58	0.09	1.05	0.36
Downforce	4.47	0.014	9.37	<.001	2.17	0.11	1.16	0.34	0.73	0.54
Speed*Downforce	7.79	<.001	1.14	0.37	0.41	0.86	0.86	0.54	0.24	0.95

Vibration S.D.: Vibration standard deviation; EVI: Emergence velocity index; F: F-value; P: P-value (<0.05).

The vibration standard deviation (Vibration S.D.) increased with planting speed (Table 3). When the planter was moving at 6.4 and 8 Km/h, the Vibration S.D. was greater compared to the 4.8 Km/h speed. Similar results were found by Badua et al. (2021), testing the application of two downforce loads (620 and 980 N) with a target seeding depth of 5 cm for corn seeds, at four different speeds (7.2, 9.6, 12.0, and 16.1 Km/h), and on two different field conditions (no-till and strip-till). The authors found that the acceleration (row-unit vibration) increased when the ground speeds increasement. Similarly, Staggenborg et al. (2004) affirmed that as planter speed increases, seed metering and placement may be also compromised, since planter speeds could increase row-unit vibration.

Vibration variability was also influenced by the downforce, according to the results presented on Table 2, when using 665 N, the Vibration S.D. was smaller than 444 N. The load increase could explain the reduction on vibration variability. According to Newton’s third law, for every action, there’s one opposite reaction. Since the loads are helping to break the soil resistance to penetration (soil reaction force), the vibration could also decrease. When the loads are lower and there is not much gauge-wheel load (downforce margin) to support the furrow opening, the vibration could increase.

Table 3: Tukey test for vibration standard deviation (Vibration S.D.) and seeding depth differences with respect to travel speed and downforce levels.

Speed (Km/h)	Vibration S.D. (m/s^2)		Seeding Depth (cm)	
4.8	1.24	a		
6.4	1.55	b	-	
8.0	1.54	b		
Downforce (N)				
870	1.45	ab	6.05	A
755	1.40	ab	5.74	A
665	1.32	a	5.56	A
444	1.56	b	4.79	B

Different letters on columns shows significant differences between the means at 1 or 5% significancy level.

Seeding depth was closer to the target depth when using higher (870 and 755 N) loads on the dynamic planting mode (Table 2). Several authors have reported that using low or no downward forces could decrease seeding depth on several crops (Badua et al. 2021; Karayel and Šarauskis. 2011; Oliveira et al. 2021; Virk et al. 2020). When there are high loads available for opening the furrow, the soil reaction force decreases, allowing the opening disks to place the seeds deeper in the furrow. Grotta et al. (2008), evaluating the effect of closing wheels pressure and different seeding depths on peanuts emergence velocity, plant height, and yield found that peanuts planted closer to 6 cm resulted on greater yield than 4 cm or 8 cm seeding depths.

The response of Vibration S.D. with respect to downforce and planting speed is shown on Figure 4. When using 665 Newtons, the intercepts where higher at 4.8 Km/h, and after 6.4 Km/h the

Vibration S.D. tended to decrease. Meanwhile, at 755 and 870 N, the row-unit vibration tended to increase after 6.4 Km/h. In this way, at lower loads (444 and 665 N), the vibration variability was bigger than higher loads (755 and 870 N) when the planter was moved at 4.8 Km/h. In this case, the lower loads (444 and 665 N) application could be leading to high vibration at lower speeds.

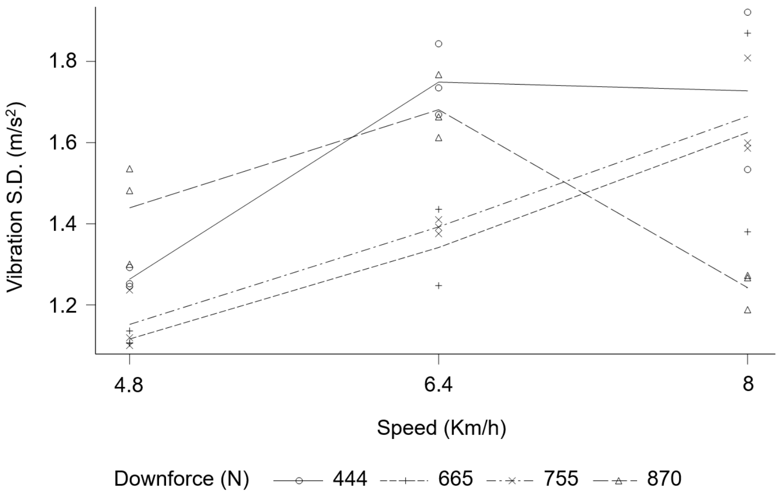

Figure 4. Interaction graph between speeds and downforce for vibration standard deviation (Vibration S.D.) using dynamic mode downforces.

m/s2: Meters per square second; N: Newtons; R2: Coefficient of determination; Km/h: Kilometers per hour.

The general linear regression models of Vibration S.D. as a function of downforce (four levels) and planting speed (three speeds using dynamic mode) are shown on Figure 5. There was a significant decrease on the vibration S.D. when increasing the downforce and planting at 8.0 Km/h. Also, the coefficient of determination suggests that approximately 50% of the vibration is explained by the downforce at 8.0 Km/h. A decrease trend on de vibration variation with downforce increase is also shown at 6.4 Km/h. The decrease on vibration according to the loads increasement could be explained by the loads increasement. Similar results were found by Badua et al. (2021). There wasn't increase or decrease trend on the vibration standard deviation with 4.8 Km/h speed when using different loads on dynamic mode.

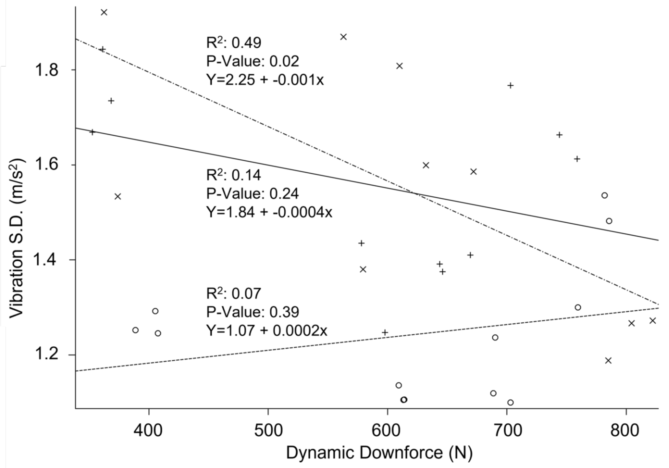

Figure 5. General linear regression for vibration standard deviation changes with respect to different planting speeds and downforce on dynamic mode.

m/s2: Meters per square second; N: Newtons; R2: Coefficient of determination; Km/h: Kilometers per hour.

The heat map (correlation analysis graph) shown on Figure 6 corresponds to the Pearson correlation between the data collected (Seeding Depth, Downforce, EVI, Plant Spacing, Planting

Speeds, Vibration S.D., and Yield). Moderate and positive association was found between downforce and seeding depth, according to Dancey & Reidy (2004) classification. In this way, the downforce increase, breaking the soil resistance was responsible for a proportional increment on seeding depth. Similar results were found by Oliveira et al. (2019), when evaluating the performance of a planter using different vertical loads for peanut planting at different seeding depths, found that using higher loads, peanuts seeding depth was closer to the planting target.

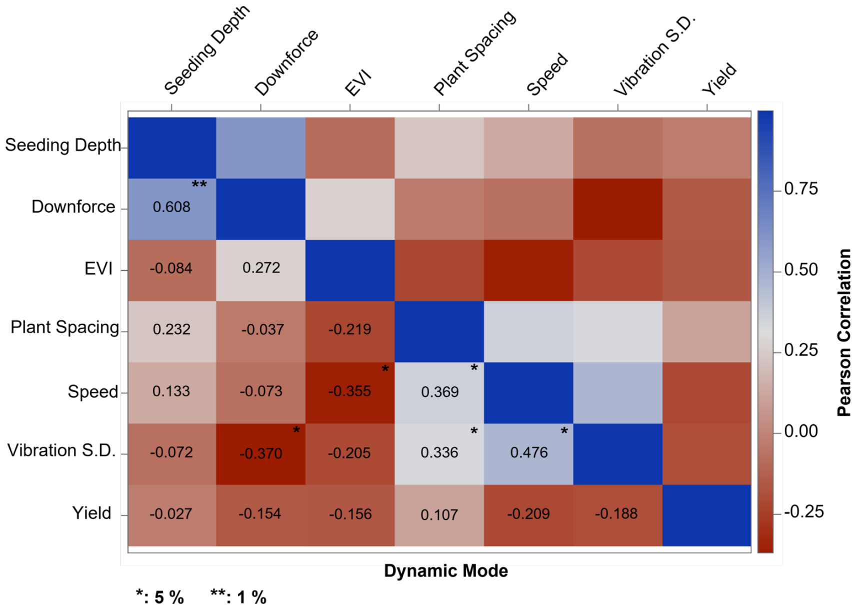

Figure 6. Pearson correlation heatmap for dynamic mode downforces. Numbers inside of the squares represents the Pearson correlation. *: P-value <0.05; **P-value <0.01.

Planter speeds were also negatively associated with emergence velocity index (EVI), and positively associated with plant spacing (Figure 6). The negative association demonstrates that when the planter speed was increased, there was a proportional decrease on the emergence velocity index, and when the planter speed was increased, plant spacing was incremented. None of the two situations above are ideal. Emergence velocity decrease can lead to un-uniform plant population, in which plants will compete for light and nutrients, also, bigger spacing between plants can open space for weeds. Results agree with Staggenborg et al. (2004) which stated that as planter speed increased, the seed metering velocity increase could potentially reduce the efficiency of the metering process. Even though the seed meters of the present trial are electric and independent of the tractor speeds, going at higher speeds could cause row-units to bounce as previously seen on Table 2, and on Figures 4 and 5, causing metering issues, or making the seeds to ricochet into the seed delivery tube, and possibly create planting gaps.

Negative and moderate association between downforce and Vibration S.D. were also found, meaning that as the downforce was incremented, there was a vibration decrease. Row-unit Vibration S.D. was also positively associated with plant spacing.

Static Downforce

Significant differences were found between the Vibration S.D. submitted to different speeds (Table 4). Seeding depth was significantly different between the downforces, and there was interaction between speeds and downforce for peanuts yield. There were no differences between emergence velocity index and plant spacing at different speeds or downforces.

Table 4: S Analysis of variance (ANOVA) for Vibration S.D., seeding depth, plant spacing, and yield submitted to static mode loads

	Vibration S.D.		Depth		EVI		Plant Spacing		Yield	
Source of Variation	F	P	F	P	F	P	F	P	F	P
Speed	11.13	0.002	3.30	0.07	2.02	0.17	1.65	0.23	1.30	0.30
Downforce	0.28	0.60	29.63	<.001	2.94	0.11	0.54	0.47	3.59	0.08
Speed*Downforce	0.19	0.83	0.58	0.57	0.15	0.86	0.22	0.80	4.45	0.03

Vibration S.D.: Vibration standard deviation; EVI: Emergence velocity index; F: F-value; P: P-value (<0.05).

Vibration standard deviation was increased with speeds increment (Table 5). Speeds of 4.8 Km/h showed less variation than 6.4 or 8.0 Km/h. Badua et al. (2018), evaluating a static hydraulic downforce system with low, medium, and high settings found that by increasing the speeds, the row-unit vibration was decreased. The results found by the authors support the results of the present study. The variability on the vibration at higher speeds suggests that the loads were not sufficient to minimize the row-unit vibration.

Seeding depth was significantly affected by the vertical loads. At higher downforce setting (870 N), seeding depth was deeper than when using 444 N. The same situation was verified when using dynamic mode loads (Table 3).

Table 5: Tukey test for Vibration S.D. and seeding depth on static mode loads

Speed (km/h)	Vibration S.D. (m/s^2)		Seeding Depth (cm)	
4.8	1.19	a		
6.4	1.51	b	-	
8.0	1.66	b		
Downforce (N)				
870	-		5.78	B
444			4.45	A

Different letter on column shows significant differences between the means at 1 or 5% significancy level.

The interaction graph between static mode downforces and speeds for peanuts yield is shown on Figure 7. Yield intercepts started close to 6100 Kilograms per hectare, when the sowing procedure was done at 4.8 Km/h, but after 6.4 Km/h, the yield was slightly incremented on the high downforce setting (870 N) and decreased when using low downforce setting (444 N). As previously seen on Figure 3 B, the amount of applied downforce did not reach the target and got decreased with speeds increasement, therefore, the high downforce application, compared to the high speed could create a better environment for the seedlings emergence and plant development.

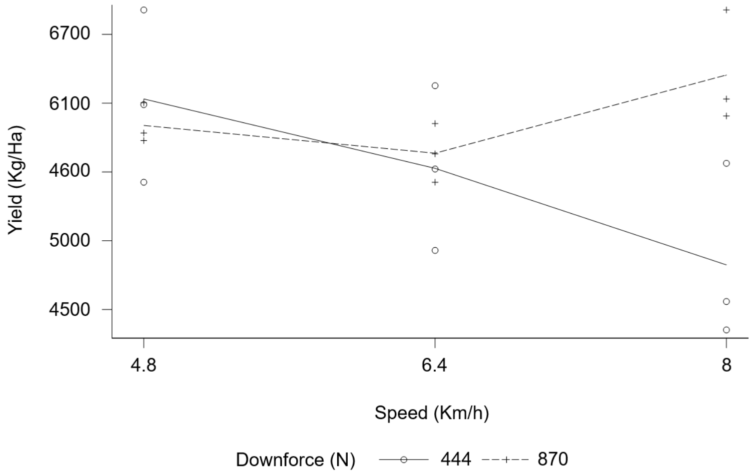

Figure 7. Interaction graph between speeds and static downforce for peanuts yield

Kg/Ha: Kilograms per hectare; N: Newtons; Km/h: Kilometers per hour.

By observing the general linear models for vibration standard deviation submitted to different static downforce and planter speeds (Figure 8), it was found a vibration decrease trend at 6.4 and 8 Km/h. Similar results were shown on Figure 5. The decrease on the vibration deviations is due to loads increasement, that possibly break the soil resistance, keeping the planter row-unit more stable.

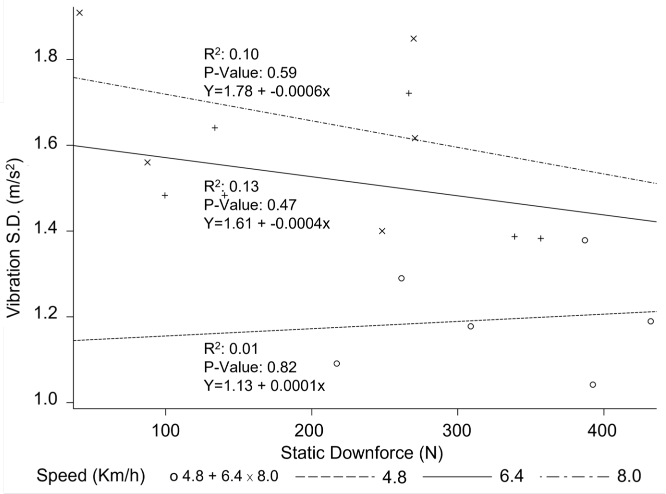

Figure 8. General linear regression for vibration standard deviation submitted to different speeds and downforce on static mode.

m/s2: Meters per square second; N: Newtons; R^2: Coefficient of determination; Km/h: Kilometers per hour.

Strong and positive Pearson correlation between downforce and seeding depth was found on the static mode (Figure 9). The strong correlation between these two variables means that when the independent variable (Downforce) was increased, there was a proportional increase on the dependent variable (Seeding depth).

The emergence velocity index (EVI) was positively and moderately associated with downforce and seeding depth according to Dancey & Reidy (2004) classification. The positive association indicates that when the downforce and seeding depth were increased, the plants velocity to emerge was also incremented. With that, the downforce increment from low to high were possibly responsible for creating a better environment for the seeds to germinate and emerge faster. With the deeper seeding depth, seeds were also able to capture more water to start the physiological germinative processes. Grotta et al. (2008) studying the effect of different seeding depths, and closing wheel pressures (0, 98, 196, and 294 N) didn’t find significant differences between peanuts emergence velocity and the downforce caused by the closing wheels, but the authors found that it took less days for the peanuts plants to emerge when planting shallow. The authors results are not in agreement with the present work. A possible explanation is that in the present work the downforce varied from 444 to 870 N, which, in the high setting (870 N) was able to provide not only deeper seeding depths, but also better seed-to-soil contact.

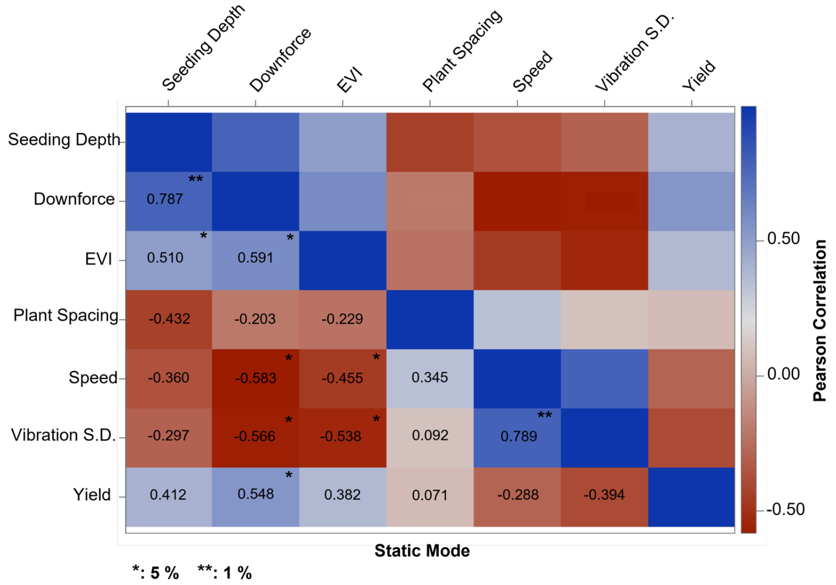

Figure 9. Pearson correlation heatmap for static mode downforces. Numbers inside of the squares represents the Pearson correlation. *: P-value <0.05; **P-value <0.01.

Planter's downforce was also associated with planting speeds (Figure 9). With speeds increasement, downforce was decreased. Similar results are expressed on Figure 3. The results are in accordance with the ones found by Badua et al. (2018). The decrease on the downforce is possibly related to the row-unit vibration created by the displacement speeds, which in conjunction with the soil reaction force restrain the downforce system to keep the target loads.

High positive association between planter speed and row-unit vibration standard deviation was found (Figure 9). In this way, results suggest that with speeds increasement, there was a proportional increase on the vibration standard deviation. The lower loads application previously observed on Figure 3 for the static mode could be one of the reasons for the high association between speeds and row-unit vibration standard deviation. The Vibration S.D. was also negatively and moderately associated with the downforce and emergence velocity index. That possibly happened because of the loads increasement. As far as the emergence velocity index, the results suggests that with the vibration increasement, planting performance was also decreased. In this way, seed bed formation, as well as seed-to-soil contact were impaired by the row-unit vibration.

The positive association between downforce and yield could be attached to the better seed-to-soil contact and/or the seeding depth provided by the higher loads.

Conclusions

This study was conducted to verify if the loads exerted by an electro-hydraulic downforce system within different planter speeds has influence on row-unit vibration, peanuts seeding depth, emergence, plant spacing, and yield. The supported conclusions are shown below:

Independent of displacement speeds, the loads exerted by the hydraulic downforce system on the dynamic mode are uniform and closer to the target when compared to the static mode. The loads on the static mode for the determined depth (6.3 cm) are applied under the target, and with the speeds increasement the downforce tends to decrease.

Under the downforce on dynamic loads, row-unit vibration is incremented at higher planter speeds (6.4 and 8.0 Km/h). The vibration standard deviation is also increased when loads of 444 N are used for planting peanuts. Using the static mode, the loads didn't show differences for vibration, but high speeds also increment row-unit vibration.

On both operational modes (dynamic and static), seeding depth is incremented when the loads are increased from low (444 N) to high settings (870 N). At higher planting speeds (6.4 and 8.0 Km/h), the Vibration S.D. shows decrease trend when using high loads on both operational modes.

Row-unit vibration standard deviation is decreased after 6.4 Km/h when using 665 N of downforce on dynamic mode, and there's an increasement on yield when peanuts are planted using the static downforce mode with 870 N with speeds above 6.4 Km/h.

Pearson correlation also showed for the present work that seeding depth is positively associated with downforce increasement, meaning that the seeding depth was increased when downforce was incremented. Row-unit vibration is negatively associated with downforce, meaning that on this work, when the downforce was incremented, the vibration was decreased on both operational modes. Speeds increasement are associated with vibration increasement on both operational modes, but when there were less loads available, which is the case of the static mode, the emergence decrease was associated with vibration standard deviation increasement.

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