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Planter Downforce Technology for Uniform Seeding Depth

Static Downforce System

Proper planting at target depth places seeds in the available moisture zone and provides good seed-to-soil contact for even germination and emergence. Given appropriate planting time and target depth where right moisture exists, seeds placed shallower or deeper than target depths have exhibited faster or delayed emergence, respectively, and at times, inadequate root development. Seeds planted deeper than expected/optimal planting depth could result in decreased/delayed emergence and this is a potential cause of poor crop development (Nafziger, 2009), all of which can result in a reduction in grain yield from 6 to 22 percent (Carter et al., 1992). Consistent seed depth is a key component because uniform seeding depths result in more uniform final plant population, proper nodal and brace root development, and can lead to higher yields. **Appropriate load on an individual row unit transferred from the toolbar, referred to as downforce,** is critical to achieving uniform and consistent seeding depth.

The planter gauge wheel arm travel is set to permit the opening discs to reach the target seeding depth during planting. Traditionally, the weight of the row unit along with a fixed additional load or force derived from a mechanical spring system (Figure 1) permits adjustment of spring tension, providing the necessary load for proper functioning of the opening discs, gauge wheels, and closing wheels. The available load or downforce is used by three key components in the following ways (Figure 2):

1. opening discs to create a seed furrow in the soil at a target depth (F_O);
2. provide sufficient loading on the gauge wheels, hereafter referred as gauge wheel load (F_G), to maintain uniform contact with the soil surface during field operation; and

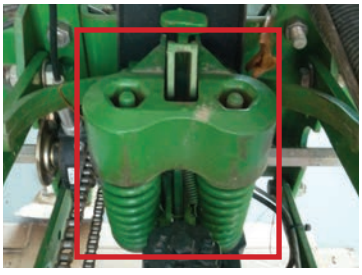


Figure 1. Mechanical spring (within red box) for downforce control.

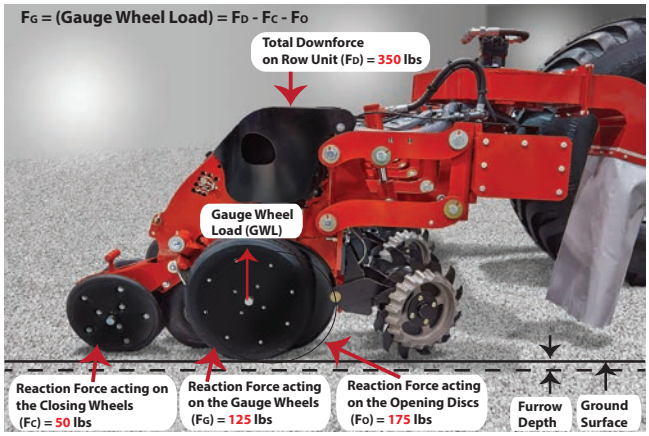


Figure 2. Planter downforce action on individual row unit components. Total downforce (F_D) is sum of row unit load and applied downforce.

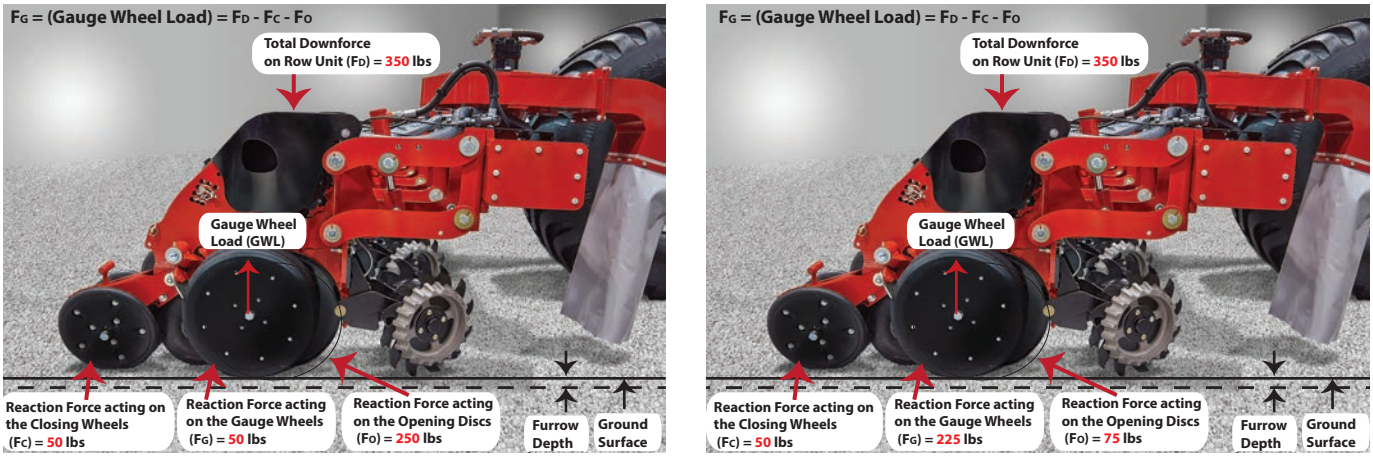


Figure 3. Differences in planter gauge wheel load between planter operation in high clay and/or moisture — heavier (a) and coarse to medium textured — lighter (b) soil using a mechanical spring downforce system.

3. maintain the closing wheels in the proper working position (F_C) to close the furrow.

Gauge wheel load is also commonly referred to as "margin." The target load on a gauge wheel is also called "margin" because this the additional load available and any proportion of it can be utilized by the opening discs as needed without compromising seed depth. The gauge wheels are responsible for maintaining the target seeding depth. Therefore, sufficient gauge wheel load is required so the planter components remain in contact with the soil while giving the opening disc adequate amount of load to penetrate the soil to create the furrow.

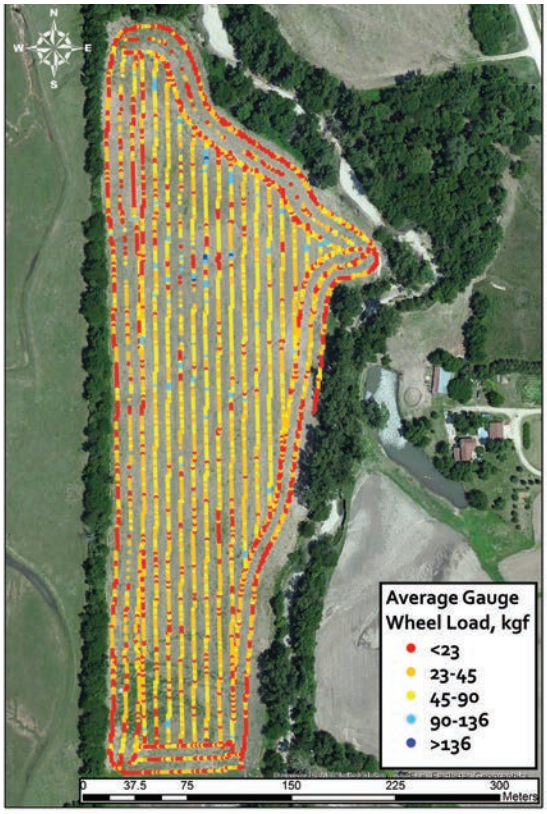
During field operation, the planter is typically set up during the initial passer within the field. During this process, seed depth and possibly spacing are evaluated to ensure proper setup for specific field conditions. A person will qualitatively assess gauge wheel load to complete the setup. Once the planter is set, operators usually do not repeatedly check planting depth and presume the setup is appropriate for within the entire field as well as field-to-field operation. However, within a field soil texture and moisture, and machinery management, i.e. planting speed, frequently vary, which may alter the opening disc load requirements and overall net gauge wheel load.

Both disc load and gauge wheel load are essential to achieve uniform planting depth. The static downforce systems using mechanical springs do not provide operators any feedback via an in-cab display regarding the effect of varying soil conditions or planting speed on static spring downforce adjustments that might be warranted when moving across the field. For example:

1. Planter operation in high clay and/or moisture (typically referred as heavier soil) will a) increase the required load on the opening discs, b) decrease the available gauge wheel load, and thus c) increase the chances of planting at too shallow depths that might result in early or no emergence (Figure 3a).
2. Planting operation in coarse to medium textured (typically referred as light to medium) soils requires less load by the opening discs, thereby increase the available gauge wheel load, and thus increase the chances of excessive side wall compaction, which may result in delayed emergence, no emergence or improper root development (Figure 3b).

Therefore, a mechanical downforce system is unable to compensate for varying conditions within a field because the system is not able to change downforce onto the row-unit as soil texture changes. It should be noted that mechanical downforce system control resolution is typically constant across the full planter width. However, row-to-row soil resistance variability (due to factors such as soil texture, soil moisture, compaction from wheel traffic, terrain, planting speed, etc.) could require a unique real-time downforce setup for each row.

Research conducted at Kansas State University using a planter equipped with mechanical downforce through constant pressure hydraulic system indicated that real-time gauge wheel load varied across the field (Sharda et al., 2016) as the planter traversed through



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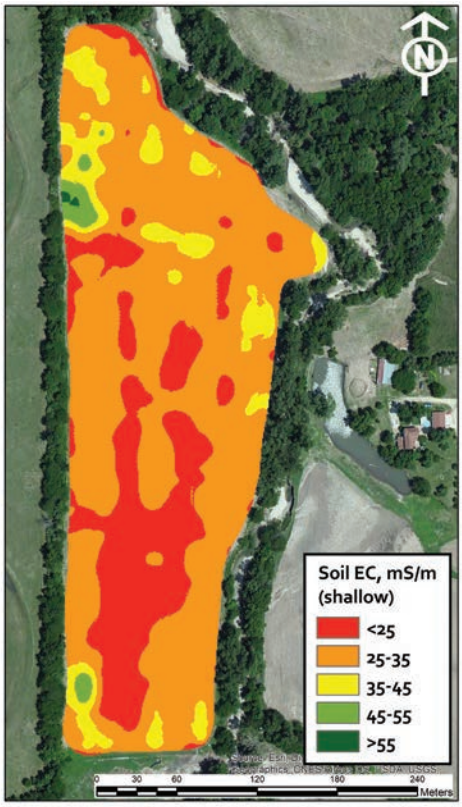


4b

Figure 4. Average gauge wheel load (a) and soil EC (b) for an example field.

areas with varying soil texture or electrical conductivity (EC) (Figure 4). EC measurements have been correlated to soil properties such as texture, drainage condition, and subsoil characteristics (Kitchen et al., 2003; Grisso et al., 2009). Results (Sharda et al., 2016) also indicated that gauge wheel load decreased as soil EC increases (Figure 5). It can be observed that gauge wheel load on soil with a lower EC was higher (an average of 37 kilogram-force (kgf), due to decreased F_O) than the gauge wheel load on soil having a higher EC (an average of 27 kgf). The difference was due to the fact that the planter row unit opening discs experienced higher soil resistance (increased F_O) on heavier soil texture (i.e. lower EC) thereby exhibiting lower gauge wheel loading (F_G). On the other hand, in soils with lower EC, the planter row unit opening discs experienced lower soil resistance (reduced F_O) and exhibited greater loading on the gauge wheels (F_G).

The results also highlighted that static downforce could not maintain uniform gauge wheel loading due to the soil texture and moisture variability that typical exists in the fields (Figure 4). Therefore, an active control downforce system is needed to apply required downforce and maintain target load distributions for opening discs and gauge wheels.

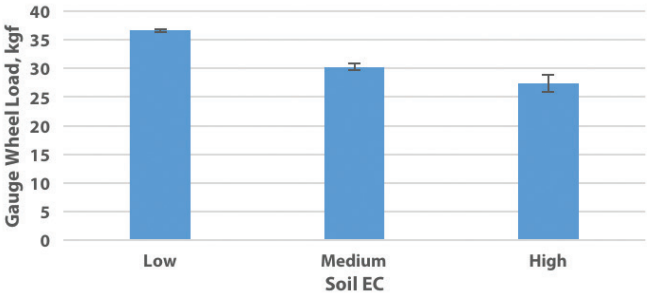
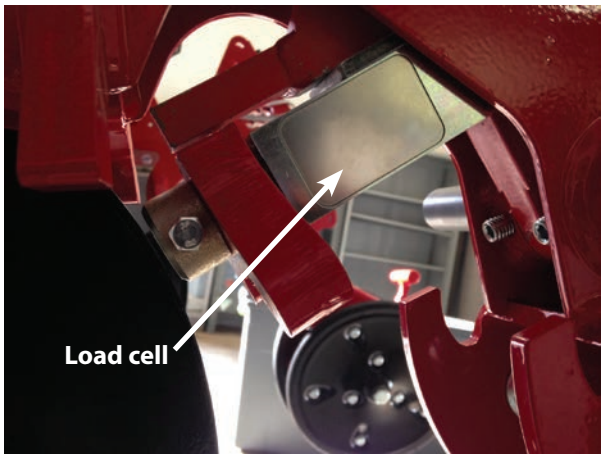


Figure 5. Average gauge wheel load decreased with increase in soil EC for the field when using mechanical downforce through constant pressure hydraulic system.

Determining the amount of downforce needed can be difficult because it is affected by variables such as soil texture, tillage, moisture, residue conditions, terrain, and planter speed. However, for a planter without a central commodity delivery system, the weight of row hoppers plus seed decreases as the hopper empties, thereby changing the total downforce. Varying gauge wheel load may result in non-uniform seeding depth (Hanna et al. 2010 and Neto and Lopes, 2012) and sidewall compaction (Hanna, et al. 2010 and Raper and Kirby, 2006). Appropriate downforce is required to achieve the target seeding depth along with optimum seedbed conditions. Conversely, if excessive loading of the gauge wheels occurs, such as in coarser

6a



6b

Figure 6. Smart pin (a) and load sensor (b) mounted on the cam assembly placed across the gauge wheel arms to estimate real-time gauge wheel load.

soils and/or moist soils requiring less reaction force acting on opening discs (F_O), the result is sidewall compaction that can lead to poor root development. Literature showed that draft requirements for seed openers is higher for heavier soils compared to lighter soils (Collins and Fowler, 1999). This situation would require greater force for the seed opener for soil penetration and reduction of ground contact of the gauge wheels, which could result in a shallower planting depth (Monsanto Learning Center, 2016).

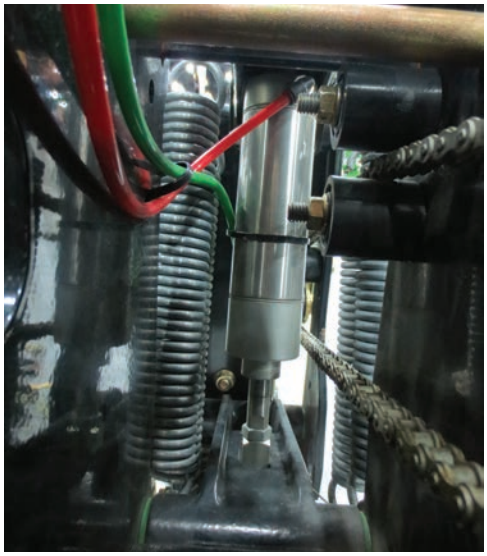
In addition to the above scenarios, vertical movement of row units (up and down due to terrain, speeds, etc.) would also change transferred downforce from spring to row unit (F = kS, Hookes law). The change in transferred downforce from spring would be due to the change in the length of the spring (S term in Hookes law). However, an active downforce has the capability to maintain a consistent gauge wheel load under dynamic field operating conditions.

Technology Basics

Today, row unit downforce can be automatically controlled by real-time sensing and feedback of downforce load distribution between opening discs and gauge wheels. In an automatic system, the user enters the target gauge wheel load, or margin, into the field computer. Load cells are installed to sense gauge wheel load and transmit real-time feedback to the controller. In a typical commercial system, the number of load cells depends on the designed planter downforce control resolution. There are systems with variations such as 1) load cells on 1 to 3 row units for the whole toolbar; 2) load cells on 1 or 2 row units for each control section; and 3) load cell on each row unit. A control section is the number of rows that would be simultaneously controlled based on feedback from the load cell(s). So for example, if one hydraulic/pneumatic control block simultaneously manages downforce on four row units then the planting system is using a four row control section, and if it manages downforce on every single row unit then it is an individual row control section. Load cells can be mounted at different locations but essentially they measure gauge wheel load and provide feedback through the row unit module to the controller. Load cells can be mounted by replacing the gauge wheel mustache pin with a "smart pin" (Figure 6a); alternatively, custom-designed load cells can be mounted on the cam assembly placed across the gauge wheel arms (Figure 6b).

Operation

An active downforce control system measures real-time gauge wheel load and compares it with the programmed target load in the controller. The control system averages gauge wheel load from all load cell(s) and adjusts the downforce for the designed control section (row-by-row or designed control section) if it is out of acceptable bounds. During field operating conditions, the control system actuates the hydraulic or pneumatic system to either increase or decrease the row unit downforce so as to maintain the gauge wheel load or margin within the programmed target load. If the real-time gauge wheel load decreases from the target value, the downforce system exerts additional pressure on the row unit through parallel linkages to increase the downforce/gauge wheel load and vice versa in case gauge wheel load increases. The required downforce for an individual row unit is implemented using a hydraulic or a pneumatic downforce system.



7a

7b

Figure 7. Example of pneumatic (a) and hydraulic (b) downforce technologies.

A commercial pneumatic type downforce system uses airbags or liftbags inflated by a hydraulically driven compressor to automatically control real-time downforce. Currently available downforce technology of this type includes the John Deere Seedstar XP, AirForce by Precision Planting and Great Plains (Figure 7a). On the other hand, the hydraulic downforce systems replace the mechanical springs or air bags with a hydraulic cylinder(s) to automatically control the downforce. The hydraulic system to control downforce on individual row units is available for Case IH, Kinze, Horsch, John Deere, and most other planter models (Figure 7b).

Some downforce systems, such as DAWN Equipment's hydraulic RFX system, implement instantaneous adjustments based on soil conditions by monitoring the row-unit using an X-Sense fluid coupling down pressure sensor. The sensor filters out mechanical vibration and noise created by planter gauge to make an accurate downforce adjustment. Typically, a hydraulic downforce system reacts quicker than the pneumatic system.

Benefits

The active downforce system provides several technological benefits including:

1. Maintains planting depth uniformity as field conditions vary, such as terrain and soil texture and moisture.

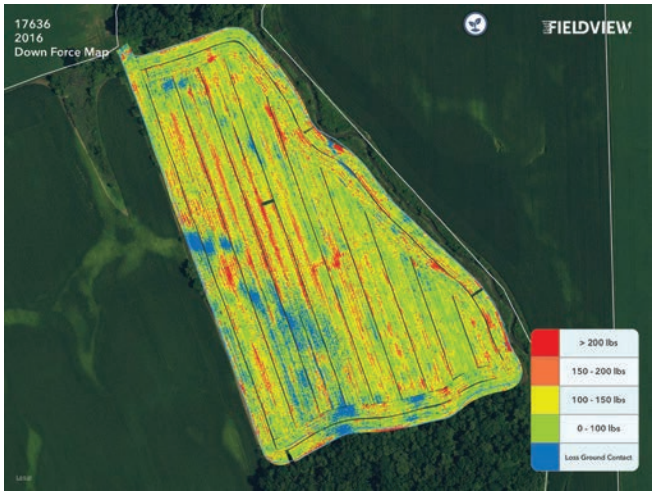


Figure 8. Example of as-planted data showing spatial gauge wheel load variability. Regions in blue, orange and red indicate planting conditions where seed may not be placed at target depth.

2. Automatically maintains the optimum gauge wheel load that ensures accurate seed placement without creating side-wall compaction.
3. Greater control resolution to apply variable downforce with changing field operating conditions.
4. Minimize row unit bounce and vibration as terrain and field conditions (e.g. rocks, clods, etc.) are encountered during planting.
5. Adjustment of applied downforce or margin from the cab to meet field conditions.
6. Ability to collect as-planted data for verification and identification of in-field variability (Figure 8).

Components Needed and Functionality

Gauge wheel load sensor:
Provides real-time gauge wheel load feedback to control the applied downforce actively.

Hydraulic actuator:
Actuated through controller-based feedback from the gauge wheel load sensor to adjust applied downforce on the row unit.

Hydraulic manifold block:
Typically uses PWM valve control technology and high pressure hydraulic oil flow to actuate hydraulic cylinders, thereby adding or reducing the amount of applied downforce on the row unit.

Pneumatic airbag:
Actuated based on feedback from the gauge wheel load sensor to add or subtract the applied downforce on the row unit.

Air compressor:
Mounted on planter to provide the air supply and pressure to automatically control the level of pressure in airbags based on feedback from the gauge wheel load sensors.

Individual row downforce module:
Sensing and feedback from the gauge wheel load sensor to adjust applied downforce on the row unit and actuated through the hydraulic control system.

Field computer/In-cab Display:
Display, monitor, record as-planted data and provide interface for programing the down-force setting from the cab.

Downforce System Components

The newest hydraulic downforce systems are available in a number of variants. End users can select a pneumatic system along with load cell(s). A pneumatic system will require an air compressor, which can be powered though an electrical or a hydraulic system, with pulse width modulated air control to regulate high pressure air flow into and out of the pneumatic cylinder; and requires airbags or pneumatic cylinders. A hydraulic system will need a hydraulic block with pulse width modulated flow control to regulate high pressure hydraulic oil flow into and out of hydraulic cylinder; and hydraulic cylinders. Some of the example components are shown in the table on the next page.

Summary

Planter downforce should be carefully selected based on soil type, moisture, terrain, and crop residue. It is recommended to consult with equipment manufacturers for proper implementation of this technology. It is also recommended to do ground in-field checks to make sure the selected planter settings are providing the target depth. For more information on products available from different manufacturers please visit the manufacturers' websites provided below.

More detailed information on commercially available products

www.agleader.com/products/seedcommand/hydraulic-down-force/

www.deere.com/en_US/parts/parts_by_industry/ag/seeding/depth-control/depth-control.page

www.horsch.com/us/produkte/saemaschinen/einzelkornsaemaschinen/maestro/maestro-sw/

www.precisionplanting.com/#products/airforce/

www.precisionplanting.com/#products/deltaforce/

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