Active Downforce System Opening Disk Load Variability During Planting Operations

Consistent seed placement is important

Plant growth and development are highly influenced on how seeds are placed in the soil at planting. Consistent seed spacing and depth allows the seeds to have the right moisture and soil contact for ideal emergence. Studies have shown that uniform spacing, leading to optimum plant stand and ultimately increased yield (Nielsen, 2004), while inconsistencies in seed placement resulted in yield loss (Liu et al., 2004 & Doerge et al., 2002). Planting depth can also influence crop stand results as variation in depth results in poor emergence uniformity which intensifies interplant competition and ultimately resulted in yield losses (Kimmelshue et al., 2022 & Stewart et al., 2018). To achieve these conditions, proper selection and implementation of planter downforce settings during planting are crucial.

What is downforce?

Grower's fields typically consist of different types of soil and each soil have different physical characteristics. One of them is soil resistance. To penetrate the soil and place the seed at the desired depth, you need to overcome soil resistance. To achieve this, downforce should always be higher than the soil resistance (Fig. 1).

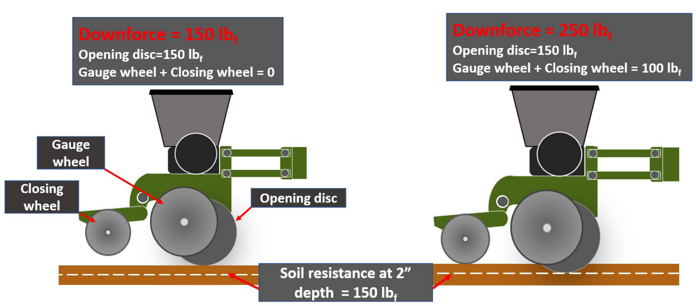

Figure 1. An illustration showing the importance of having enough downforce on the row unit to achieve desired seeding depth. Without enough downforce, opening disc will not reach the desired seeding depth.

Downforce is the summation of vertical forces acting on the row unit which consists of the weight of the row unit itself and additional load applied through mechanical, pneumatic, or hydraulic systems necessary to achieve the desired seeding depth. During planting, downforce is distributed to the three main soil engaging planter components namely: gauge wheels, opening disc and closing wheels. Some portion is taken up by the opening disc for soil penetration, some portion is used by the closing wheels to gently scrape soil and cover the furrow and the rest of the load is carried by the gauge wheels. This excess load is typically referred to as gauge wheel load (GWL) or margin. It is essential to maintain a certain amount of margin as it ensures that the gauge wheels remain in contact with the ground thus desired seeding depth is kept consistent during planting. The margin can be used anytime by the opening discs when additional load for soil penetration is needed.

Downforce varies during planting

Essentially, lighter textured soil (sand) has lower soil resistance while heavier textured soil (clay) has higher soil resistance. Planting on heavier textured soil (clay) may require greater amount of downforce for the opening disc to penetrate the soil to the desired depth. In dry years this is especially important as we want to place seed into moisture. Adequate depth control and downforce is necessary for uniform trench depth and emergence. Dry soils are "harder" and require more downforce. Lack of proper downforce can cause parts of the seeded field to be planted to shallow, not into moisture, and therefore can result in delayed emergence compared to where downforce was adequate to place the seed into moisture. This can cause problems at harvest time when the field does not mature and dry down at the same time. However, selecting the amount of downforce to be applied during planting should be done carefully. While it is important to always maintain an optimum level of load on the gauge wheel to prevent shallow planting, soil compaction may happen when load on the gauge wheel is too much (Hannah et al, 2010). In contrast, insufficient margin could cause low row unit ride quality, row unit bounce, which could result in uncertain seeding depth and non-uniform seed spacing (Badua et al., 2018). Thus, proper downforce selection is critical to achieve desired seed placement consistency.

How is downforce implemented?

Downforce can be applied through mechanical, pneumatic, or hydraulic systems, which enable operators to adjust the load applied based on the field conditions at planting. These systems can be categorized as static/fixed or active depending on how they implement downforce. Row-crop planters equipped with the mechanical downforce system are able to implement fixed/static downforce only while those that are equipped with pneumatic or hydraulic downforce systems are capable of implementing fixed/static or active downforce.

Fixed/static downforce system

The fixed/static downforce is a system where downforce is adjusted manually. It consists of heavy-duty mechanical springs which can be manually set to apply additional fixed amount of downforce (for example, 125, 250, or 400 lb_f). Growers typically select one downforce setting at the beginning of the growing season and apply it throughout the entire field. However, field conditions vary across the field. This downforce system is unable to compensate for these varying conditions within a field because the system only applies constant downforce across the toolbar. Similar field variability concerns can also arise during planting season when farmers pause the planting operation, expecting potential rains to add moisture. Measuring field characteristics and manually changing downforce during planting requires too much time, leading to inefficient planting operations.

Active downforce system

Active downforce is a system that automatically adjusts downforce while planting. This system is equipped with airbags or hydraulic cylinders mounted to the planter row unit. It collects information and processes these in real-time, allowing also for adjustments on-the-go. This system provides a more consistent downforce compared to a mechanical spring system, resulting in a uniform seeding depth and good seed-to-soil contact across the field. An active downforce control system consists of load cells mounted on each row unit, providing real-time gauge wheel load signals. The control system automatically adjusts the downforce by comparing the load measured by the load cells to a programmed target gauge wheel load. The target load is selected by the operator, which is just enough to maintain desired seeding depth without worrying about soil compaction or shallow planting. During planting, the hydraulic or pneumatic system is activated by the control system to either increase or decrease the downforce in order to maintain the target gauge wheel load.

Evaluating downforce system performance during planting

Understanding downforce system response during actual planting operations allows growers to select the desired setup for their field to maximize planter performance. This enables them to achieve the desired conditions (for example, uniform seed placement,

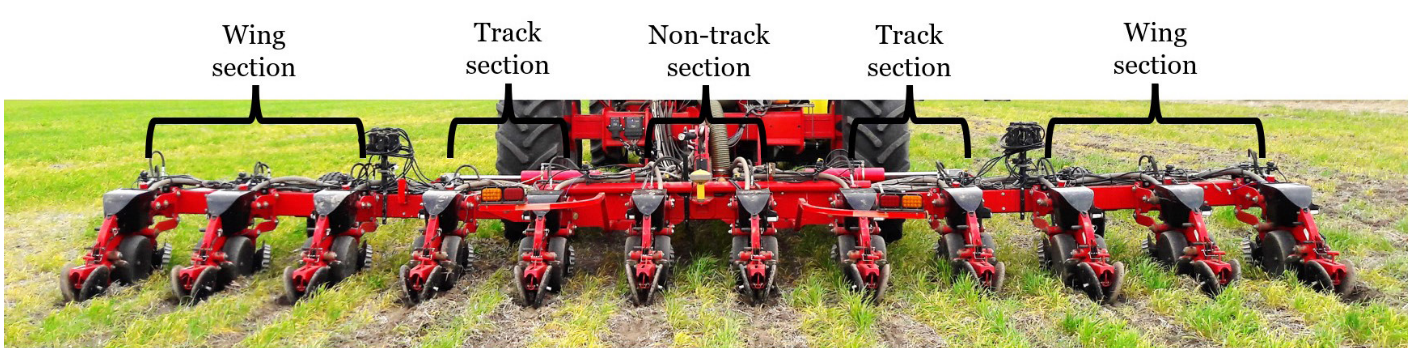

Figure 2. The planter toolbar where the row units are mounted and how they are segregated into sections.

seed-to-soil contact) for optimum yield, leading to sustainable productivity in their operations.

A study was performed using a 12-row unit planter to quantify opening disk load during planting operations and to assess opening disc load requirement across varying field conditions. The planter was equipped with a hydraulic downforce system. Row units were segregated into sections: wing, track, and non-track sections (Fig. 2). Row units for each section were installed with load cells and hydraulic transducers to measure applied gauge wheel load and hydraulic pressure, respectively. These sections were used to analyze opening disc load across the planter toolbar.

Two corn production fields in Kansas with contrasting field management strategies were examined (Table 1). Field variability was described using the apparent soil electrical conductivity (ECa).

Table 1. Conditions of the experimental fields.

Field	Soil Series	Area	Irrigation	Tillage
A	Crete silt loam	29.9	Pivot	No-till
B	Wymore silty clay loam	26.3	No	Strip-till

Soil ECa measures soil's capacity to conduct electricity, which can be used as an indirect indicator of a number of physical and chemical soil properties, including clay content. Due to strong correlation between ECa and particle size and soil texture, sandy soil tends to have low conductivity and clay soils have high conductivity (Grisso et al., 2009); hence, low ECa zones are likely to contain lighter soils (such as sand) while high ECa zones are associated with heavier soils (such as clay). Soil ECa data was used to split the field into various regions representing low, medium, and high ECa (Fig. 3).

Collected machine data from the mounted sensors were utilized to calculate actual opening disc load. The potential of opening disc to lessen or augment soil compaction was analyzed using the recorded real-time GWL and hydraulic pressure readings while creating two scenarios with low and high downforce implementation. The two scenarios are as follows:

Scenario 1: Margin was set at 100 lbf

Scenario 2: Margin was set at 200 lbf

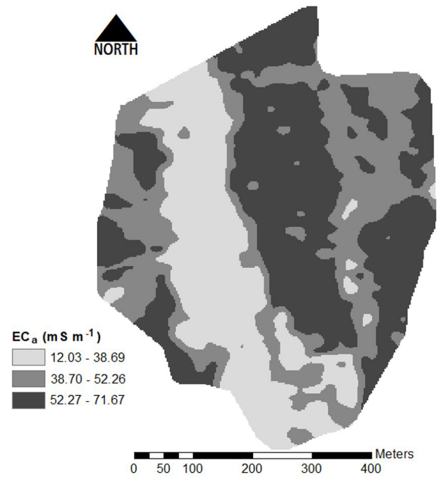

Figure 3. One of the examined fields split into ECa classes to delineate field variability.

To illustrate an ideal situation for scenario 1, total downforce on the row unit was 250 lbf. If 50 lbf load was set to be taken by the closing wheels and margin was set at 100 lbf then there is 100 lbf load left for the opening disc. If the soil resistance at an instance was 80 lbf, there is an excess of 20 lbf load which is added to the load carried by the gauge wheels. This situation is called uplift because the extra load on the gauge wheels could potentially result to soil compaction. Meanwhile, if soil resistance at a certain instance was 150 lbf, then there is a deficit of 50 lbf. This load can be taken from the margin. But since margin was set to maintain 100 lbf, it will actuate the system to apply additional load to compensate for the load taken by the opening disc; therefore, this situation is called downforce. In summary, uplift is needed to prevent soil compaction while downforce is needed to maintain the desired margin.

Uplift and downforce events across planter toolbar during planting operation

Results from the study revealed that planting on both fields showed the instances uplift was needed ranged from 16% to 22% of the total planting time in a 100 lbf margin scenario. The wing section showed the highest number of events requiring uplift followed by the non-track section (fig. 4).

While the planter is designed with a standard weight transfer system that evenly distributes weight along the toolbar, a high percentage of uplift events could indicate excessive vertical movement at the far end of the toolbar, leading to scenarios where row units

Figure 4. The frequency of events (%) of uplift and downforce across row unit sections for both scenarios in fields A (left) and B (right).

either press too deeply into the ground or float above it (hillside or terrace operation). Meanwhile, row units placed in the center of the toolbar or the track section experienced less movement and could be more stable, resulting in fewer events of uplift. As expected, increasing the margin to 200 lbf reduced the frequency of needing uplift. More load allocated to the gauge wheels means lesser load left on the opening discs. As such, the downforce system will need to provide more load to meet the opening disc load requirement, as shown by the increased downforce events, indicating that with this scenario soil resistance was more than the opening disc load. This leads to a portion of the margin being used by the opening disc most of the time. Maintaining an ideal amount of margin is critical to ensure the target depth is always maintained. Dynamic conditions during planting could require sudden opening disc load changes. With enough margin, opening discs will have sufficient load to overcome soil resistance to reach the desired depth while the downforce system adjusts to maintain the target margin.

Field variability and track compaction due to machine operation require varying opening disc load requirement

The study performed a generalized linear model (GLM) and Spearman's rank correlation coefficient tests and reported a modest but significant correlation between opening disc load and soil ECa. Opening disc load increases as the planter move from low soil ECa zones to high ECa zones (Table 2).

Table 2. The parameter estimates of the GLM and Spearman's correlation coefficients between opening disc load and soil ECa zones

Coefficients	Field A	Field B
Low (Intercept)	996.6	579.0
Medium (β_1)	24.3	70.7
High (β_2)	86.2	30.9
Correlation (ρ)	0.16†	0.14†

†Significant correlation at $p < 0.0001$

To explain, transitioning from low to medium ECa zone in field A indicate that opening disc load is expected to increase by 24.3 lbf, while opening disc load will further increase by 86.2 lbf when moving from medium to high soil ECa zone. Findings support previous research showing clay soil requires higher draft force due to its higher bulk density and soil penetration resistance (Muhsin, 2017) Such results indicate creating a seed trench at the desired depth requires varying opening disc load across the field. Results could help operators choose the most suitable margin level for their field and assist manufacturers in optimizing planter control to achieve uniform load distribution across the planter toolbar, ensuring proper seed placement throughout the field.

Summary

Understanding opening disc load distribution during planting provides the following benefits and recommendations:

Real-Time feedback and control

Real-time opening disc load allows operators to receive immediate feedback such that adjustments can be made to optimize downforce settings based on changing soil conditions, terrain, and other factors ensuring that the planter maintains depth consistently across the entire field.

Balancing depth and ideal soil conditions

Achieving the desired seeding depth along with optimum environment around the seed is essential for uniform emergence. Hence, opening disc load could help growers assess the optimum margin to maintain target depth while minimizing soil compaction.

Hydraulic uplift to minimize soil compaction

Opening disc load requirement across the toolbar could provide feedback when hydraulic uplift is needed. This prevents excessive pressure on the soil along any sections across the toolbar. Likewise, this could assist manufacturers in optimizing planter control to achieve uniform load distribution across the planter.

Compaction tracks or compaction

Excessive opening disc load on certain rows during a pass indicates compaction tracks and excessive disc load across the toolbar typically indicates compaction zone which could be due to farm history. Both of these scenarios can help farmers to identify such zones and potentially implement tillage operations in select areas to reduce excessive compaction. In terms of operational dynamics, downforce system would manage target margins and disc loads when driving along the compaction tracks and zones, but the system may miss rapid adjustment when planting across the compaction track (for example field track from combine operation).

In summary, a proactive approach to downforce management, along with real-time feedback, empowers operators to optimize planting performance. Field conditions vary and the ability of the planter to make adjustments on-the-go are key to uniformity in seeding depth and emergence.

More detailed information on commercially available downforce systems:

https://www.caseih.com/en-us/unitedstates/products/planting-seeding

https://www.deere.com/en/planting-equipment/

https://www.fendt.com/us/products/planters/fendt-momentum

https://www.horsch.com/us/products/planting

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