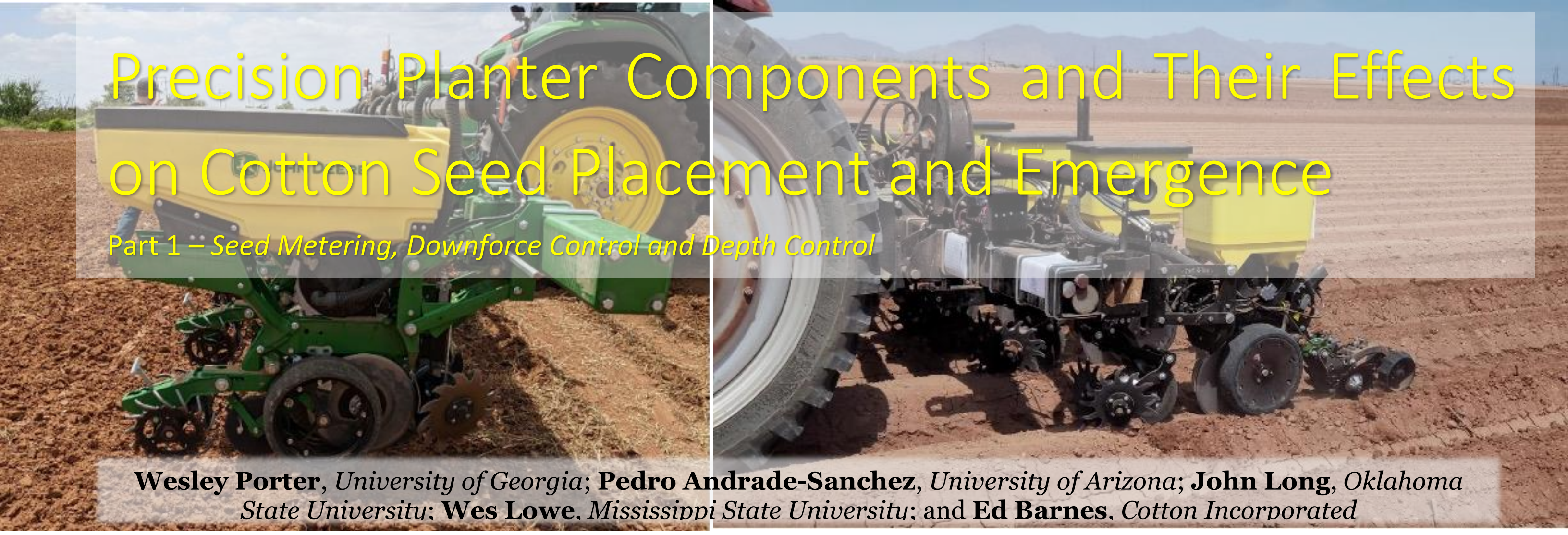

Precision Planter Components and Their Effects on Cotton Seed Placement and Emergence

Part 1 – *Seed Metering, Downforce Control and Depth Control*

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Establishing a strong plant stand is the first step in achieving a productive cotton crop. Cotton can be more difficult to establish than other row crops such as soybeans or corn, thus it is important that the planter is properly configured for the soil type, residue, and soil moisture conditions. Furthermore, some of the new planter controls can often allow a faster planter speed without sacrificing plant emergence rates. This paper focuses on proper: 1) seed metering, 2) downforce settings, and 3) planting depth for your planting conditions including new options to automate these settings. A future paper will consider other advances in planter technology such as new seed delivery systems and control systems for closing wheels. For additional information on planting into high residue cover crops, see a companion paper at this link.

Seed Metering

Placing the desired number of seeds per length of row starts by establishing an ideal target plant population for your conditions. Many studies have shown that cotton yields are relatively insensitive to uniform plant stands ranging from 15,000 plants per acre to 80,000 plants per acre (for more details on proper plant populations see this link). Seeding rate selection considers the risk of having a low plant stand due to poor seed germination and/or seedling emergence. Other factors include seed cost and opportunity cost as dictated by the planting date. Although, at first glance, overseeding may appear to only increase your seed cost, the unnecessary expenses associated with establishing an excessive number of plants per row foot quickly accumulate through the year. Effective implementation of precision planting technologies will decrease seeding rate and result in significant seed and other input savings. When selecting your seeding rate, it is important to consider both the stated germination rate of your planting seed and expected planting conditions (e.g., dry, wet, cold, or ideal). An equation in the Appendix of this paper can be used to calculate a seeding rate. A key factor in planning when to start planting is soil temperature and forecast rainfall. A decision aid to help incorporate current and forecasted weather conditions into selecting a planting date is available from this link. Once the target seeding rate is determined, different factors must be considered to achieve consistent seed delivery based on the type of drive used by your planter as described in the following sections.

Ground Drive

With a ground drive metering system, one or more frame support (drive) wheels are connected to a series of hex shafts, chains, and/or gearboxes that directly power each seed meter simultaneously. The seeding rate is set manually by selecting the proper combination of driver/driven sprockets to achieve the desired rotational speed of the seed plate and thus attaining the desired seed spacing. Sprocket selection is made while the tractor/planter is not in motion, therefore, it is not practical to make changes to the rotational speed of the driven planter shaft throughout the field operation. Seed metering should be set for the predominant field conditions and planting populations expected for the field. Note that each planter comes with its own seeding rate chart and ensuring proper gear ratio is selected for the target seeding rate is important as this is one of the most common mistakes (selecting wrong sprocket size) that happens on ground wheel driven planters. Non-ideal conditions such as rough surfaces, tall beds, or excessive slow or high speeds can result in inconsistent seed metering due to drive wheel slippage. Slippage can be minimized by adjusting the position of the drive wheel in relation to the frame to maintain good ground contact, checking proper tire inflation, selecting a more aggressive tread pattern, and providing proper toolbar weight (see Downforce section).

Hydraulic Drive

With a hydraulic drive, the entire planter or planter sections are driven by one or more hydraulic motor(s). Planter ground speed must be independently measured using a wheel hall effect pick-up sensor, radar, or GPS. Since the rotational speed of the metering system is set by the amount of flow delivered to the hydraulic motor and no longer solely impacted by ground speed, seeding rate can be adjusted on-the-go for each independent hydraulic drive. Some hydraulic drives may also have row clutches to provide overlap shut-off and turn compensation. Note that in extreme climates, planter shaft rotational speed may vary as function of hydraulic fluid temperature. It is important to bring hydraulic fluid to normal operating temperature before setting the desired seeding rate. Aftermarket hydraulic drive units can be retrofitted to a ground drive planter.

Electric Drive

Electric drive is the most advanced type of seed metering mechanism. Electronically controlled seed metering is obtained through high-torque electric motor drive units coupled to each seed meter capable of delivering a wide range of variable output speeds, and changes in rotational speed take place instantaneously. Unlike mechanically driven planters, the number of shafts, sprockets, and chains are eliminated altogether on the whole planter as the seed meter on each row is electronically driven. Individual row control including compensation for turns, speed of operation, and seeding rate adjustment is typically incorporated into the design of each electric drive system. Since each drive must be interfaced with a planter controller, real-time monitoring of planter performance including mapping of planter parameters such as actual seeding rate is possible (also true for hydraulic drives). Controller changes in electric drive output speed are immediate, much quicker than hydraulic drives.

Downforce

Downforce is the weight applied directly to each row-unit transferred from the planter frame to force the furrow openers down into the soil. Applied downforce is countered by the soil reaction at the row unit gauge wheels, therefore proper planter frame ballast is key to achieve proper downforce control. It is one of the most critical components on the planter for achieving target seed depth and appropriate levels of force in the seed trench. Cotton should be planted around 0.5” to 1.25” deep on average across the Cotton Belt with desired depth being heavily influenced by soil type, texture, and moisture; thus, with this narrow window depth, it is critical to place the seed at the appropriate depth relative to soil surface considering the soil and environmental conditions at the time of planting. Seeds planted too deep will struggle to emerge. Seeds planted too shallow run the risk of running out of moisture or being exposed to high temperature leading to reduced germination or stand establishment. Also, poor seed-to-soil contact caused by inadequate downforce can result in rapid loss of moisture and stop germination. The following sections discuss different ways downforce can be controlled during planting.

No Downforce Control

Planters without any type of downforce control can be common in certain cotton producing areas due to lack of perceived issues, or expense of the system; however, this configuration usually does not promote consistent seed depth placement, especially when varied soil textures and conditions are prevalent in a single field. Planters without any type of downforce control are not recommended for cotton since cotton is planted shallower than other crops, and without downforce control, the risk of seed on top of the ground is very high. Planting speed must be decreased for some soil conditions to reduce the risk of poor seed placement. Moreover, in soils which are difficult for the planter unit to penetrate, additional downforce is necessary to cut the soil and create a well consolidated seed trench.

Spring

Spring downforce is a good option for its simplicity and expense, but growers can sometime miss the target seed depth if drastic moisture or soil texture changes occur within a field. Improper spring settings and adjustments can result in seed being placed too deep or too shallow. Like other planter manual settings, spring downforce settings cannot be changed on-the-go and may be impractical to change frequently on some planter models (Figure 1). At the least, spring downforce should be adjusted from field to field and when soil conditions change.

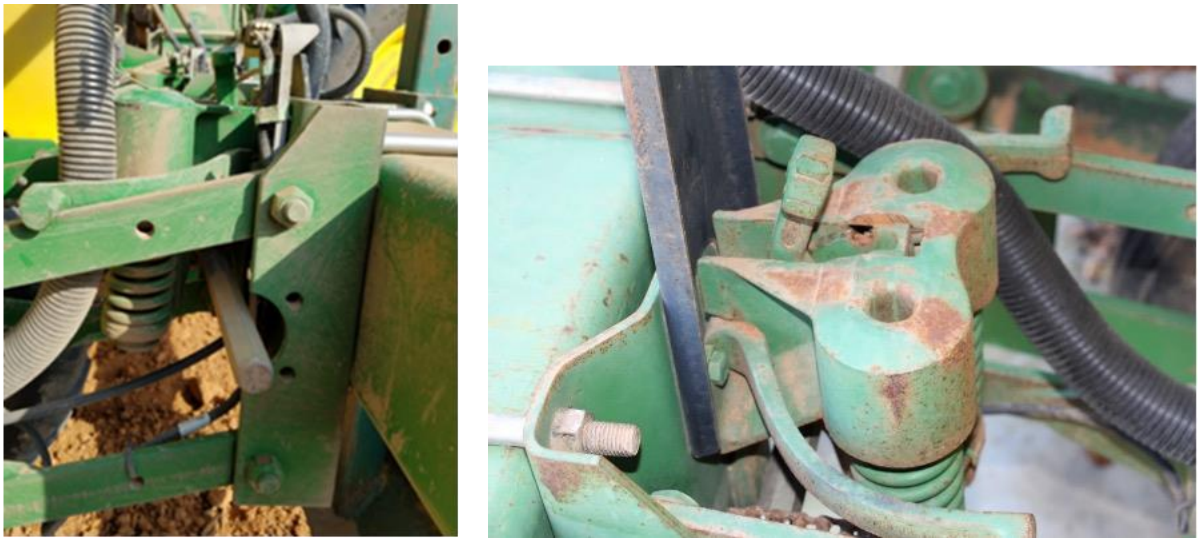

Figure 1: *Mechanical (spring) downforce system. Left image is the sideview of the spring mechanism and the right photo shows the T-bar handle used change spring tension.*

Pneumatic

Pneumatic downforce systems require compressed air to pressurize an air bag to transfer a mechanical load to each row-unit (Figure 2). They are typically continuously adjustable across a range of downforce values for each row, or a section of multiple rows, using an electronic controller with load cells providing force feedback at the gauge wheel position, the controller is then coupled to an in-cab display where the operator can make these adjustments. Pneumatic downforce systems can better match downforce requirements for varying soil conditions than spring downforce systems because of their user-friendly adjustability, but fluid compressibility results in relatively slow response time compared to other active downforce systems which limits their real-time control capabilities in the field. Just like any downforce system, proper operation depends on available ballast weight on the planter frame. Additional ballast weight is usually provided via suitcase weights attached to the implement toolbar. Air bags in pneumatic systems mainly operate in one vertical direction pressing down the row unit against the soil surface.

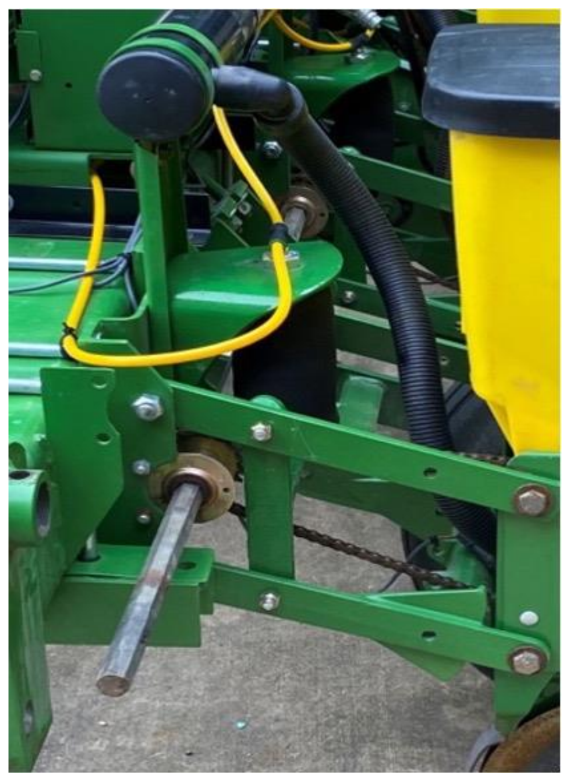

Figure 2: *Pneumatic downforce system.*

Hydraulic

Hydraulic downforce systems use high-pressure fluid power to transfer a mechanical load to each row unit retrofitted with a hydraulic cylinder / actuator. It is offered as a factory-installed option or as an aftermarket retrofit by many companies (Figure 3). This system can help in compensating for wider ranges of soil moisture and texture since it has a much faster response time than pneumatic downforce systems. This system has a similar planter frame ballast requirement as pneumatic systems. In most cases, hydraulic power is easily obtained from the tractor. Another major advantage of hydraulic downforce systems is bi-directional control and the ability to lift individual row units to transfer load back to the planter toolbar when row unit weight alone is sufficient to provide enough downforce on the row unit in loose or wet soil conditions. Too much downforce can cause excessive planting depth or compaction that may hinder germination or delay seedling emergence.

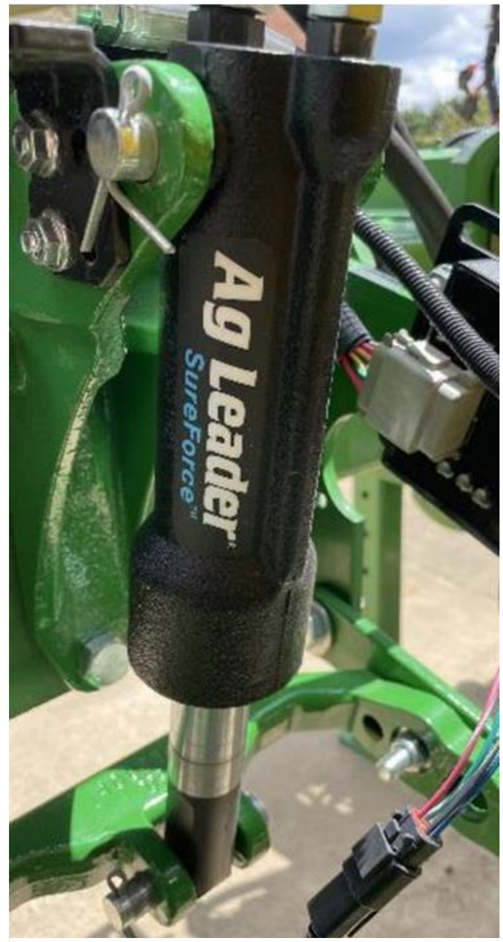

Figure 3: *Hydraulic downforce system.*

Downforce Summary

On-the-go downforce adjustments to planter row-units using an active downforce system (such as pneumatic or hydraulic) with real-time downforce control and monitoring capabilities is a feasible option to improve planting operations in fields where variable soil textures require different optimal amounts of downforce to achieve adequate seed placement in the soil. In many cases, adjustable downforce control can be achieved by retrofitting a mechanical planter if acquiring a new planter is cost-prohibitive. In situations where active electronically controlled downforce options are not used, it is important that the available passive spring-loaded downforce system is adjusted correctly as this is the only resource available for maintaining the desired seeding depth across varying soil textures or variations in plant residues within the field during planting operations. Also keep in mind that under some planting conditions, additional ballast weight may be required to achieve the needed downforce. For context on additional ballast weight in the toolbar, highly compacted soils might require upwards of 250 lbs per row unit in order to cut and break the soil to a depth of two inches.

Depth

Depending on a wide range of soil conditions, cotton planting depths generally range from 0.5 to 1.25 inches. Planter depth settings adjust the distance between the bottom of the depth gauge wheels and the bottom edge of the furrow openers. Any change in soil condition or applied downforce most likely will change the actual depth of the delivered seed relative to the top of the ground due to the compaction of soil or residue under the depth gauge wheels. Depth control in most planters is achieved with either manual (mechanical) or electronically controlled systems. Figure 4 displays the same planter row units fitted with mechanical (left) and electric actuators (right) to adjust depth settings.

Mechanical Systems

Depth settings are a function of the linkages controlling vertical position of the double disc openers. In standard mechanical systems, these discs are mechanically connected to position levers and/or threaded shafts designed for manual position adjustment. Position levers can be moved to predetermined notches, holes, or positions that represent depth limits typically in ¼" increments ranging from zero to the maximum depth allowable. It is important to perform frequent checks of depth for every row both on a hard surface and in the field to ensure all rows are placing the seed at the same depth. Yearly maintenance is also important to inspect disc bearings, adjust separation between disc openers, and replace worn out disc openers to maintain a uniform depth across all row units. Double disc openers should be replaced when worn by more than 0.5 inches. Consult your planter owner's manual for the proper way to calibrate each row unit so that the same position setting for each row results in the same depth.

Electronically Controlled Systems ("Smart Depth")

Electronic depth control systems allow for precise depth setting on the planter by partially replacing the mechanical linkages with an electric drive (currently this option is only offered by Precision Planting and the manufacturer recommends a specific depth calibration for system to work correctly). The electric drive controls the depth position limit using the planter controller and user defined depth settings to enable active on-the-go depth control. Figure 4 shows a comparison of row units with manual mechanical depth setting and retrofitted with electric drive. Just like the mechanical system, it is important to check each row unit and calibrate to the actual depth measured on a hard surface.

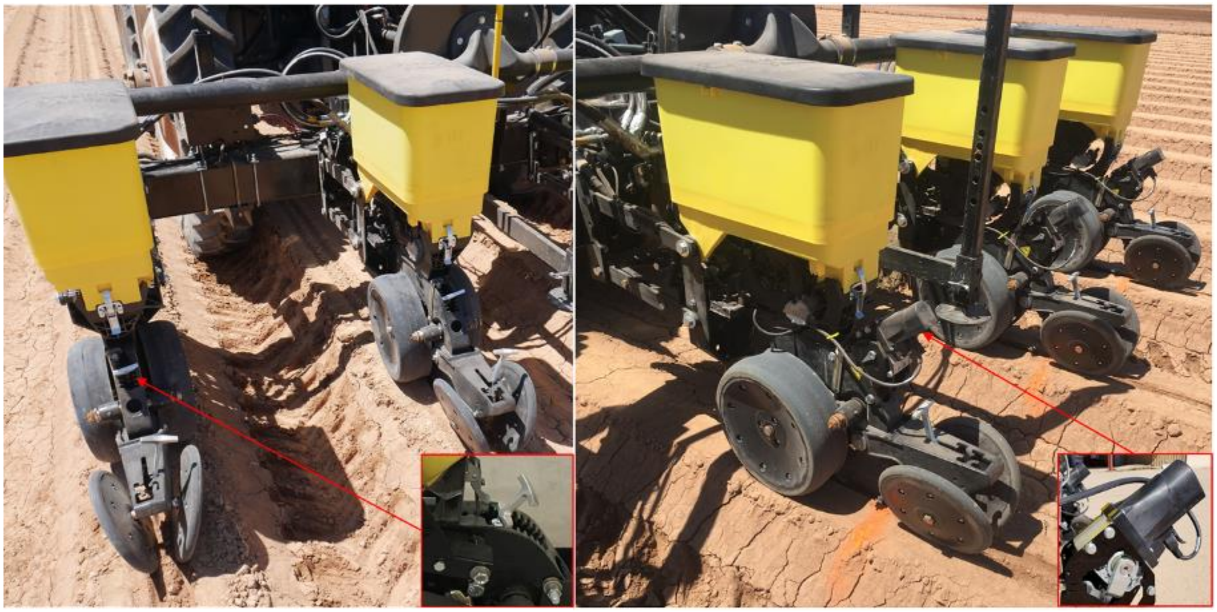

Figure 4: John Deere *MaxEmerge row units with manual mechanical depth setting (left) and retrofitted with electric drive (right).*

Soil Moisture

Soil moisture content at planting has major implications on the quality of the planting operation. It is important to realize there is a relationship between soil moisture and planter downforce. Keep in mind:

- Dry, untilled soils generally require higher downforces to ensure seeds are placed deep enough.
    - In many cases when planting on dry soil conditions, growers want to place the seed shallower to catch rainfall or shallow moisture. It is imperative that the user checks the weather, during hot and dry conditions, as dry soil can allow temperatures to spike to levels that damage the seed. If irrigation is not available and there is not a guarantee of rainfall, either place the seed deeper into moisture or delay planting until rainfall is received.
    - Planting into dry conditions has many complications (e.g., sufficient moisture for germination, but insufficient moisture to keep seedling alive, soil crusting, and inconsistent stands), so it should be avoided when planting date restrictions allow.
- Wet soils require lower levels of applied downforce to prevent sidewall compaction and excessively deep seed placement.
- Careful selection of downforce settings is needed to ensure the seed trench is mechanically stable enough to allow proper seed placement, but not so stable that the trench is not properly closed.
- Germination is highly dependent on adequate levels of soil moisture. On-the-go information on soil moisture in the seed trench enables advanced applications of

moisture-seeking systems with a combination of top/dry soil removal and depth adjustments for irrigated conditions in the far West when “wet” planted.

Soil Texture

Soil texture plays an important role in seed placement and emergence as illustrated in Figure 5 that shows clay loam and sandy soil within the same field, where adequate stands were only obtained in the clay loam soil. Soils with sandy surface layers may drain faster and tend to be dryer than silt and clay soils. High clay content soils can be more prone to crusting over, especially if compacted, and crusting is also influenced by factors like soil structure and organic matter. Increasing clay content in the soil typically requires higher downforce to achieve target seed depth. Studies in Oklahoma and Georgia have found that soil electrical conductivity zones that are often correlated with soil texture (lower conductivity often corresponds to higher sand content) and can be useful in determining when seed depth and downforce settings should be changed on-the-go in a single field.

Figure 5*: Photos of two areas of the same field planted on the same day in Georgia with different soil types. The area shown to the left has achieved a good stand of cotton where a higher clay content soil held more moisture while no plants have emerged in the area picture to the right where the surface texture had a higher sand content.*

Advanced Planter Technology Options

In addition to the key planter control parameters previously discussed like downforce and depth controls, modern planters offer additional options to help ensure a uniform plant stand is achieved. For example, a recent planter technology that can help with soil moisture, texture, temperature, and residue management is Precision Planting’s SmartFirmer (Figure 6). The smart firmer provides real time data that includes sensors that monitor soil temperature, moisture, organic matter, Cation Exchange Capacity (CEC), and foreign material in the furrow. These sensors provide the user with the ability to make real time decisions about seed placement in the soil profile during planting (note, when planting at depths than 1-inch the sensor may not be dependable due to inadequate soil contact). Other options include new seed delivery systems such as speed tubes, new closing wheel options including control systems, and advanced monitoring sensors. These topics will be discussed in more detail in a future publication.

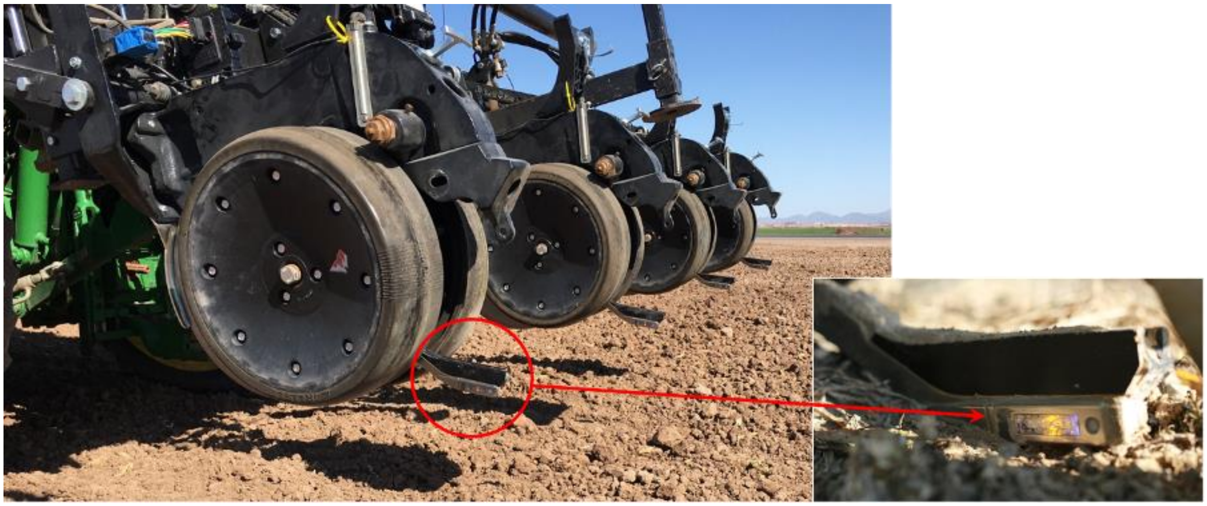

Figure 6. Precision Planting SmartFirmer with a closeup of the sensor shown to the right.

Acknowledgements

We appreciate the review of this paper by Drs. Simerjeet Virk, University of Georgia; Gaylon Morgan, Cotton Incorporated; and Dr. Tyson Raper, University of Tennessee for their constructive comments. Partial funding for the studies that provided the information in this report was provided by Cotton Incorporated.

Appendix- Seeding Rate Formula

A target seeding rate can be calculated using the formula:

$$Seeding\ Rate = \frac{Target\ Plant\ Population}{Germination\ X\ Plant\ Emergence}$$

Where,

Seeding Rate = the seeding rate to set the planter to (will have the same units used for Target Plant Population, but as number of seeds instead of number of plants),

Target Plant Population = the number of plants you want in the field after emergence is complete. Units are typically plants per acre, but the equation will work with other units like plants per row foot.

Germination = Germination rate for the planting rate as a decimal fraction (greater than 0 and less than or equal to 1) that is often provided for the planting seed lot.

Plant Emergence = Fraction of the seeds that germinate that emerge into viable plants. For ideal planting conditions the value will be close to 1, and will decrease as planting conditions worsen (e.g., low temperatures, dryer than desired soil conditions, etc.).

Example Calculation

Consider the senecio with a desired **plant population** of 35,000 plants per acre, with planting seed that has a germination rate of 80% (**germination** as fraction is 0.8). Furthermore, assume planting conditions are near ideal and you estimate that 90% of the seeds that germinate will become healthy plants (fraction **plant emergence** is 0.9). Seeding rate is now calculated as:

$$Seeding\ rate = \frac{35{,}000}{0.8\ X\ 0.9} = \frac{35{,}000}{0.72} = \mathbf{48{,}611}\ \boldsymbol{seeds\ per\ acre}$$

Effective implementation of precision planting technologies can increase the probability of plant emergence, and thus decrease seeding rate and result in seed savings by increasing estimated emergence.