

Considerations for Site-specific Implementation of Active Downforce and Seeding Depth Technologies on Row-crop Planters

Downforce by depth settings influence seeding depth

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Abstract

Planter technology continues to rapidly advance including row-by-row control of parameters such as applied downforce and seeding depth that permit real-time adjustment to varying field conditions. The objective of this research was to investigate the relationship of seeding depth and applied downforce to soil properties in order to specify required control system response to field conditions. Field experiments were conducted using a common US row-crop planter with maize (*Zea mays L.*) Two fields were selected with differences in soil texture and terrain attributes. Treatments included 3 seeding depths (2.5, 5.1, and 7.6 cm) and 3 applied downforces to each row unit (0, 113, 181 kg) that were replicated as 6-row strips within fields. Soil electrical conductivity and soil volumetric moisture content were measured the day of planting as indicators of soil texture and soil moisture, respectively. After planting, live plant density was collected along with intrusive measurements through soil excavation to verify true seeding depth. Data were analyzed using mixed effect and regression models. Seeding depth was significantly impacted by the interaction between depth setting and applied downforce on the row-units. Differences in the quality of crop establishment existed between the field-scale study sites and combinations of planter settings. In general and across all sites, deeper planting depth and heavy downforce reduced the final live population and delayed emergence for maize. Soil texture significantly affected final maize seeding depth with shallowest occurring in heavier textured soil. Field results indicated that active downforce and seeding depth technology will require as low as 0.05 second response time in order to account for soil property variation during operation. Results inferred that seeding depth and downforce will need to be controlled concurrently to maintain the target seeding depth when soil and terrain variability exists within a field.

Introduction

Planting remains one of the most, if not the most, important field operation since it impacts crop yield potential. Planter performance is usually evaluated based on the ability of a planter to reach the target plant population while maintaining uniform seed spacing and proper planting depth. Uneven seed placement can reduce maize yield by up to 5% to 10% [1]. Selection of planting depth depends on crop and soil physical properties, with the objective to place individual seeds in soil conditions (moisture, temperature, aeration) that promote minimal seed loss and uniform emergence [2]. Uniform emergence limits competition between seedlings and can improve the quality of the grain at harvest [3].

Most US row-crop planters control seeding depth through a pair of gauge wheels mounted on individual row-units. Planting depth is selected by manually adjusting the distance between the bottom of the disc openers and the bottom of the gauge-wheels operating on the soil surface [4]. A downforce setting adjusts the amount of extra-weight transferred from the planter toolbar onto individual row-units determining the pressure exerted by the gauge wheels on the soil around the seed furrow. Proper selection of downforce setting is important allowing the disc openers to achieve the target seeding depth. Too much downforce creates side-wall compaction of the seed furrow negatively impacting early root development of seedlings and reducing yield potential [5]. Downforce is traditionally applied using mechanical springs. Recently, pneumatic or hydraulic actuators are available providing the capability to actively (real-time) control the amount of additional force transferred onto row-units. New technology is also being developed to actively control seeding depth.

Soil resistance to creating a seed furrow trench depends on soil mechanical behaviour including soil plasticity, compactibility and strength [6], and is affected by soil physical properties such as soil texture, soil structure, soil water content and mineralogy. However, such physical properties vary spatially indicating planter performance could be improved by adjusting planter settings to field spatial variability [7]. Prior research indicated that seeding depth and downforce management are critical for optimization of planter performance [8] but how in accordance to spatial variability remains the question. The objectives of the study were to 1) characterize the effect of seeding depth, downforce planter setting, soil properties and field spatial variability on true planting depth and 2) discuss response needs for implementation of real-time active downforce and active seeding depth.

Materials and Methodology

The study was conducted on non-irrigated maize (*Zea mays L*) seeded to 65,480 seeds ha⁻¹ at the E.V. Smith Research Center (Shorter, AL USA; 32.441762 N, 85.897455 W). A standard John Deere planter with MaxEmerge Plus row-units retrofitted with Precision Planting eSet meter adds-ons was used. Seeding depth and downforce were adjusted manually with row-unit downforce controlled by standard, mechanical heavy duty downforce springs. Three planting depths were selected (2.5, 5.1 and 7.6 cm) with three levels of applied downforce corresponding to none, medium, heavy (0, 113, 181 kg). Two fields provided different soil properties and terrain attributes such as slope and aspect. Soil moisture content tended to be higher in Field A than in Field B due to heavier soil texture and poorer drainage. Fields were strip-tilled prior to planting.

The experiment was arranged as a split-plot design. Field constituted the whole plot and combinations of depth and downforce settings organized based on a randomized complete block design within individual fields with 4 blocks in Field A and 3 blocks in Field B. The trial was conducted in strips, with one planter pass corresponding to one treatment. Data were collected on each plot across 6 (Field A) or 9 (Field B) transects in order to compensate for the unbalanced number of blocks and account for field spatial variability. Three variables were measured. True planting depth was characterized at each sampling site as the average between four depth measurements; and individual depth measurements were determined by excavating an emerged corn plant and measuring the distance between the soil surface and visible seed. Final live population was determined at each sampling site by counting the number of emerged plants along a 1.5 m distance for each of the four middle rows of the strip. Soil electro-conductivity (soil EC) was measured prior to planting using a Veris 3100 Soil EC sensor. The experiment was replicated during 2014 and 2015.

Analyses of variances using mixed effect models were computed to characterize the effect of different treatment combinations on true planting depth and final live population. Response time requirements for implementation of active downforce and seeding depth technologies were evaluated by characterizing field spatial variability using the magnitude and intensity variation in soil EC. A model was developed to resolve the effect of magnitude changes of soil EC on true planting depth for given combinations of planter settings. Results were combined to associate changes in the magnitude of soil EC to a range of distance within individual fields assuming different levels of accuracy on true planting depth. Distance were ultimately converted into response times assuming planting speed of 5 to 9 km h⁻¹.

Results and Discussion

Results indicated that both seeding depth and downforce settings affected true seeding depth and crop establishment (characterized as final live plant population) for both fields and years. Increasing depth settings contributed to significantly increase true planting depths, with final true planting depths of 4.3, 5.8 and 6.8 cm for respectively 2.5, 5.1 and 7.6 cm target depth. True planting depth at 2.5 and 5.1 cm depth setting was significantly deeper than the target whereas for the 7.62 cm treatment, depth was significantly shallower than the target (Figure 1). Even though differences were not significant, increasing downforce setting tended to increase true planting depth (year, field and treatment depth confounded), with true depth estimates equal to 5.3, 5.7 and 5.8 cm for respectively none, medium and heavy downforce. In particular, downforce influenced resulting planting depth the most for the 5.1 cm treatment depth with significant differences existing. Soil texture significantly affected final maize seeding depth with deepest depths occurring in Field B, with 6.0 cm average true depth versus 5.2 cm in Field A.

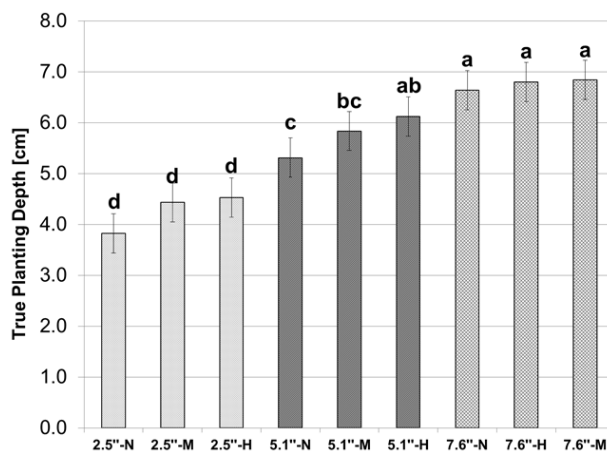


Fig. 1: Effect of Treatment Depth and Downforce Setting on True Planting Depth

Explanations to results include the disc openers easily achieve shallow planting depth as planter weight is transmitted mainly onto the gauge wheels, which coincide with the limited influence of downforce on true final seeding depth during shallow operation. As depth increased, soil resistance increased making it difficult for each row-unit to reach the target seeding depth. At 5.1 cm planting depth, increasing downforce increased the load transmitted onto planter gauge-wheels which contributed to increased true final seeding depth. At 7.6 planting depth, the toolbar did not provide sufficient counterweight onto the row-units to transmit the increase in downforce onto the row-unit disc openers, which could not meet the target depth.

Final live plant population was significantly influenced by downforce and seeding depth. In general, live population was reduced as seeding depth increased. Maximum percent live population occurred for the 2.5 cm treatments but yield was not included for this analysis. On average, percent live population was reduced by 4% between the 2.5 and 5.1 cm treatments, but by 10% comparing the 5.1 and 7.6 cm treatments. For the 5.1 and 7.6 cm treatments, increasing downforce contributed to reducing live population. Explanation to results include that 2014 and 2015 were characterized as wet years for spring planting. Soil moisture content was not a limiting factor for maize germination but soil tended to be saturated after planting, generating the persisting presence of standing water in low areas up to several days after planting and resulting in slower emergence and increased seed loss as planting depth and downforce increased. Thereby, results demonstrated that the interaction between depth and downforce settings was significantly affecting true planting depth and final live population, verifying the importance to appropriately select seeding depth and downforce level to maximize crop establishment for current field conditions. Further, field and year significantly affected the response of the planter supporting the notion that depth settings and downforce must be adjusted for individual fields and for each growing season.

Concerning spatial variability, soil texture and soil moisture content varied with fields and weather conditions in both 2014 and 2015. Soil physical properties dictate soil mechanical behavior, and therefore soil resistance to furrow opening varied with changes in soil texture and moisture content. Results showed that spatial variability in soil properties within individual fields was significantly affecting planter performance, justifying the need of adjusting planter settings with field spatial variability.

Response time requirements for implementation of active downforce and seeding depth technologies depends on 1) the level of accuracy desired on true planting depth, 2) planting speed and 3) the level of field spatial variability. In the fields used in this research, results showed that response time needed may be as low as 0.05 seconds or 20 Hz. Using a US row-crop planter example, a ground speed of 8 km hr^{-1} with a $\pm 0.6 \text{ cm}$ tolerance on seeding depth would require a response time of between 0.1 to 0.4 seconds to account for soil spatial variability experienced by the planter. For today, it remains impractical to implement and control active seeding depth and downforce concurrently, but results highlight the need for such systems to optimize planter performances. A response time on the order of 1 to 2 seconds would be more realistic using current technology solutions thereby enabling these planter settings to be adjusted in accordance with macro- soil variability versus micro-scale variability.

ty. Successful implementation of real-time technology to adjust planter settings to field variability would rely on optimizing the selection of both planting speed and the level of desired accuracy for the target planting depth for the technology to respond suitably to obtain uniform and accurate seeding depth. This research highlighted that active downforce and seeding depth technologies can enhance seedling emergence and final maize stands by adjusting to site-specific soil conditions.

Conclusion

Results indicated that true seeding depth was significantly affected by numerous factors, including the selection of planter settings, overall field properties, the growing season and field spatial variability. Increasing the seed depth setting and heavier downforce contributed to increasing true planting depth and influenced final live population. Therefore, depth and downforce settings should be selected simultaneously to achieve the target planting depth. To maintain uniform seeding depth, results revealed that planter settings should be selected separately between fields and adjusted within fields to compensate for field spatial variability. Implementation of active depth and downforce technology could be challenging as required response times could be as low as 0.05 seconds but success would rely on optimizing the selection of both planting depth accuracy and planting speed. This research is ongoing with future steps to include yield results by year plus develop a model that considers soil parameters to characterize field variability as feedback to control these new planting technologies to improve true seeding depth of maize while enhancing emergence uniformity.

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