ROW-CROP PLANTER REQUIREMENTS TO SUPPORT VARIABLE-RATE SEEDING OF MAIZE

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ABSTRACT

Current planting technology possesses the ability to increase crop productivity and improve field efficiency by precisely metering and placing crop seeds. Planter performance depends on using the correct planter and technology setup which consists of determining optimal settings for different planting variables such as seed depth, down pressure, and seed metering unit. The evolution of "Big Data" in agriculture today brings focus on the need for quality as-planted and yield mapping data. Therefore, an investigation was conducted to evaluate the performance of current planting technology for accurate placement of seeds while understanding the accuracy of as-planted data. Two studies consisting of 2 different setups on a 6-row, John Deere planter for seeding of maize (*Zea mays L.*) were conducted. The first study aimed at assessing planter performance at 2 depth settings (2.5 & 5.0 cm) and 4 different down pressure settings (varying from none to high) with planter setup to perform a uniform seeding rate (65185 seeds/ha) at a constant ground speed (7.0 km/hr). The second study focused on evaluating planter performance during variable-rate seeding with treatments consisting of 2 seed metering units (John Deere Standard and Precision Planting's eSet setups) with 5 different seeding rates (49383, 59259, 69136, 79012 & 88889 seeds/ha) and 4 ground speed treatments (6.0, 7.0, 8.2 & 9.4 km/hr). All treatments were randomized and replicated four times. A data acquisition system was developed for monitoring and logging real-time planting variables such as meter speed and row unit acceleration/vibration with this data tagged using a differential global positioning system (DGPS) receiver in order to create spatial maps.

Field data collection for the down pressure study consisted of measuring plant emergence, plant population and seed depth whereas seed spacing, plant population after emergence along with distance and location for rate changes within the field were recorded for the variable-rate seeding study. As-planted data consisting of plant population, seed spacing and meter performance was also recorded using 2 commercially available displays for both studies and analyzed for comparing planter performance based on the actual field data. Crop yield was also measured to evaluate the effect of the different treatments on planter performance. Preliminary results indicated that down pressure impacted crop emergence. Measured seed depth was significantly different from the target depth even though time was spent adjusting the units to achieve the desired. For example, the mean depth for the 5-cm treatment was 3.8-cm in one field and 4.1-cm for another field. Seed depth results indicated variability at times based on field soil conditions which would explain the differences between the target and measured depths. Results from the variable-rate study indicated that seeding rate changes were accomplished within or less than a 1.9-m distance or a quick response time (< 1 sec) regardless of ground speed. This quick response over varying ground speed treatments indicates that current hydraulic drives minimize rate change errors. Row-unit acceleration or ride varied between individual units with one row-unit exhibiting lower ride quality compared to other units and the main toolbar. Planter field performance significantly varied for the two types of metering units. Seed metering unit setup and meter speed (dependent on ground speed and seeding rate) is critical to obtain expected performance of today's planting technology. The results showed that planter performance is dependent on meter speed, and field performance starts degrading at higher meter speeds (> 38 rpm) for both meter setups. Overall, the eSet meter performed better than Standard John Deere meter setup exhibiting more uniform seed spacing and higher crop yields. The study recommended that operators need to ensure the correct planter and display setups in order to achieve needed seed placement performance to support variable-rate seeding.

Keywords: Variable-rate, Field Performance, Seed Metering, Down Pressure, Seed Depth

INTRODUCTION

Today, farmers are charged with maximizing crop yields to provide for the growing world population while using inputs in a judicious manner to maintain profitability. During the 90's, costs of agricultural inputs started to increase plus a need for environmental stewardship materialized requiring US farmers to develop more efficient and sustainable management strategies. At the same time, the availability of the Global Positioning System (GPS) to civilians commenced the evolution of what is now known as precision agriculture (PA). GPS-based guidance along with yield mapping were the initial technologies being adopted on farms with variable-rate technology (VRT) following shortly thereafter. Since that time, these technologies have become standard options on farm equipment. Many row-crop planters come equipped with hydraulic drives and associated in-cab display enabling farmers to implement variable-rate seeding (VRS), if interested. With VRS capabilities in-house coupled with rising seed costs and inherent in-field variability, interest is high among US farmers to take advantage of this VRT as a means to manage risks and maintain profitability.

Here in the US, maize (*Zea mays L.*) continues to be the largest planted crop with about 85 to 95 million acres planted from 2008 through 2014 (USDA NASS, 2014). Planting constitutes one of the most important, if not most critical, field operations within a growing season for maize. Correct seeding population and seed placement during planting is important since these influence uniformity of emergence, crop development and yield potential. Mistakes at planting will have an effect over the entire growing season for maize; in most cases a negative impact. A seed requires absorption of soil moisture for germination (Hunter and Erickson, 1952) with soil moisture within the seed bed most affecting the timing of germination and 1st emergence. Favorable planting conditions and optimum planting performances are required for proper germination of the crop and to maximize yield potential (Carter et al., 1989). Emergence in maize can defined as the stage where the seed has germinated and starts coming out of the ground. It is commonly known throughout the US Corn Belt that uniform emergence is required to maximize yield potential. Planting requires opening of the soil, commonly termed as the furrow, to desired depth followed by placement of seeds in the opened furrow then closing of this furrow (Moody et al., 2003) using press wheels mounted on the planter. However, completion of these steps is usually not sufficient to result in good uniform emergence of seeds, especially in the Southeast US where soil variability (e.g. soil type, texture, etc.) can vary highly within a field. Numerous factors affect the quality of seed emergence with uniform emergence of maize being difficult in the Southeast US. Factors most often mentioned in literature as affecting crop emergence are soil properties (e.g. texture and moisture content at planting; Srivastava et al., 2006), depth of the furrow in which seeds are dropped, downforce (defined as the amount of pressure exerted by the planter gauge wheels on to the soil; Hannah et al., 2010) and planter performance (Nielsen, 1994). When considering the soil variability in the Southeast US, the ability to consistently place seeds at the proper depth while maintaining the target population and seed spacing can be difficult. Current, precision ag displays and VRT capabilities have provided the ability to better monitor planter performance in real-time. However, an important aspect is the quality of the as-planted data and its ability to accurately reflect the placement of seed in the field.

A major precision ag topic here in the US and worldwide is “Big Data” and how it will evolve in agriculture. While data management and Farm Management Software (FMS) packages have been around since the mid-90’s, more US farmers are interested in archiving farm generated data off machines and using it to derive information which can be used to support management decisions; data-driven decision is commonly the term to describe this process. The development of a variable-rate seeding (VRS) program for maize at the farm level requires several ingredients including the correct precision ag technology but also an understanding of the growing environment on a field-by-field basis. This understanding not only requires farmer intuition but spatial data layers as well to create management zones (MZ) in which each zone has a unique seeding rate. Common spatial layers for development of seeding MZs include a soil map, elevation data, and yield maps. Within the ag industry, the two most important data layers are yield and as-planted maps. These two layers serve to understand implementation of a VRS program and the ability to evaluate it in terms of benefits for an individual field. The absence of one of these layers makes it difficult to truly evaluate and understand VRS and can potentially create false-positive results for a farmer. One assumption of any data layer is its quality. Poor quality data leads to erroneous results and ultimately incorrect decisions. In particular, these data must be of quality to define the appropriate MZs for VRS of maize since MZs tend to be dynamic or be revised over a few years as more data is collected and what in-field, environmental aspects are driving yield. Past research has indicated quality concerns on as-applied maps and their ability to truly reflect the spatial performance of a machine equipped with VRT (Fulton et al., 2012; Virk et al., 2013). Therefore, an important component of Big Data success in agriculture relies on both the technology being adopted by farmers and the quality of spatial data layers so the analytics being developed can generate information which farmers can use in their decision process.

The study presented provides a better understanding of the current capabilities of implementing variable-rate seeding (VRS) of maize in the Southeast US. In particular, interest in VRS of maize are increasing which can be seen by the VRS services being offered by seed companies and 3rd party, precision ag data management companies. Not only must the correct technology be in place to successfully adopt VRS, data generated by precision planting technology needs to provide an accurate spatial depiction of final seeding information such as population. As-planted data in conjunction with yield maps is needed to ensure correct evaluation and fine-tuning of zone management to support VRS. The objective of this study was to verify the current performance of planting technology for accurate placement of seeds while understanding the accuracy of as-planted data.

MATERIALS AND METHODS

The study was conducted at the E.V Smith Research Center (Shorter, AL, USA) during the 2013 growing season. Real-time Kinematic (RTK) is the primary GPS correction being used on all precision ag technology at this research farm. This study used a 6-row, John Deere integral row-crop planter with MaxEmerge row units. Heavy duty down pressure springs were used on each row-unit that nominally provide no additional down force or 0.45, 1.11 or 1.78 kN of additional down force per row (John Deere product literature, Moline, IL USA). Depth control is managed using a T-handle adjustment that controls stop height for the gauge wheels on each row unit. A Trimble Rawson hydraulic control system provided the variable-rate capabilities for the planter and was operated using the Trimble Field IQ technology. A John Deere 8130 row-crop tractor equipped with a Trimble Auto-Pilot system using VRS as the RTK correction source. The tractor was used to pull the strip-till and planter. A Trimble FMX display with variable-rate and seed monitoring by-row functionality was used for all tests. A Precision Planting 20/20 SeedSense Seeding display and FieldView product were also used to monitor all seeding parameters. Each seed tube had a DICKEY-john high-rate seed sensor mounted on it to provide feedback to both the Trimble and Precision Planting technologies. Prior to planting, all fields were strip-tilled.

A planter specific data acquisition system was developed within the Biosystems Engineering for monitoring and logging real-time planting parameters. These parameters included actual meter speed and row unit acceleration/vibration with this data tagged using a differential global positioning system (DGPS) receiver in order to create spatial data for analyses. Meter speed was determined using a 3600 pulse per revolution encoder (TRD-GK series encoder by Koyo Electronics Industries Co.). A Raven Industries Phoenix 200 DGPS receiver was mounted on the planter along the centerline of the metering units. This data acquisition system was developed using National Instruments LabView program and a National Instruments USB 6225 DAQ board with a 10Hz sampling frequency used. A user interface was developed to monitor all data during field operation on a laptop or tablet. Data collected from this system was used to generate an as-planted map representing the true planting population while providing the row-unit acceleration between the left and right sides of the planter.

Three fields were selected to conduct two unique planter performance experiments. The first experiment consisted of assessing planter performance at 2 depths (2.5 and 5.1 cm) and 4 different down pressure settings (varying from none to high) for a total of eight treatment combinations. A uniform seeding rate of 65200 seeds ha^{-1}, and a constant ground speed of 7.0 km hr^{-1} with Precision Planting eSet meter setup were used for all treatments. Two fields with different but known soil properties were selected; Field 1 was a sandy-silt loam while Field 2 a clay-loam. Soil type, planting depth and downforce settings were the factors selected as treatments in this study. Initial planting depth was established by adjusting the T-handle for depth settings on the planter based on manually exposing planted seeds within buffer rows using the 1.11 kN setting. Once the 2.5 and 5.1 cm planter depth settings were established, they were used for each field. For each field, all treatments were replicated four times (Fig. 1). Each replication contained all 8 treatments and represented a differentiated area of the field. The experiment was implemented doing strip planting (one planter pass represented an individual treatment) and the treatments were randomly placed within each replication. The experimental design was based on a split-split plot design. Soil type was confounded with the fields and was considered as very hard to change factor. Based on the difficulty to assure effectiveness of the depth setting in the field, planting depth was considered as a hard to change factor. Downforce was an easy to change factor. Data collection was organized along a grid and determination of sampling site was established by drawing 6 transects across each field. Data were collected at the intersection between these transects and each pass which represented a total of 192 sampling sites.

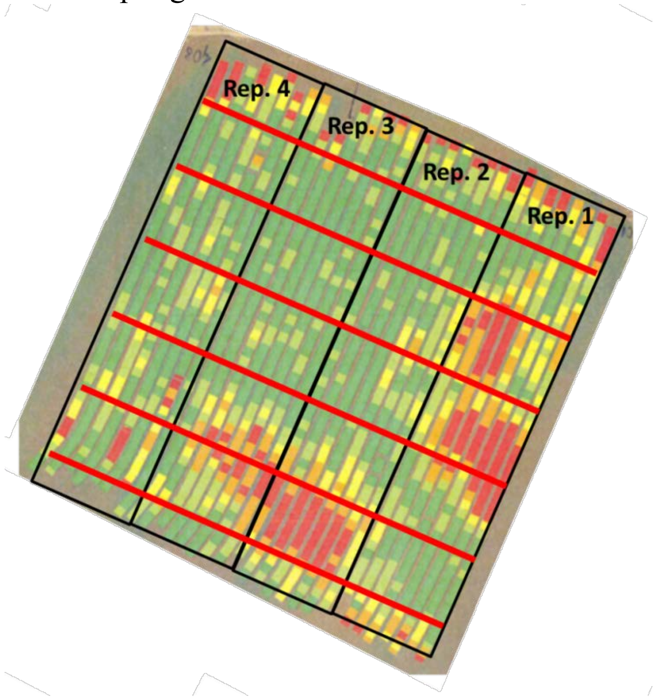

Fig. 1. Field 2 layout for the seeding depth by downforce experiment illustrating the 4 replications and the 6 transects (red lines) representing sampling sites for each plot (e.g. individual planter pass).

The following data was collected at each sampling site: soil moisture content at planting, percentage of emerged plant after full emergence, actual planting depth, and uniformity of emergence. Soil moisture content was collected at planting using a HydraProbe sensor at each sampling site. Percentage of emerged plant was computed after emergence based on population counts. Actual planting depth was measured after planting, once the maize reached the V1 to V2 growing stage and methodology consisted of extracting individual seedlings from the soil and measuring the distance between the seed and the soil surface. Eventually, average rankings for emergence were computed based on daily counts for emergence. Seedlings were classified into 5 categories: non-emerged (0), through soil surface (1), spike (2), one leaf open (3), one leaf open and second visible (4) and two leaves open (5). At each sampling site, the percentage of seedling for each stage was estimated and these percentages were used to compute a daily average ranking for emergence. These ranking indices were used as an indicator of the growing stage of seedlings at a particular time and location. If emergence would be uniform across each field, all indices would be the same value at a specific day after planting (DAP).

The second experiment focused on evaluating planter performance during variable-rate seeding with treatments consisting of 2 seed metering units (John Deere Standard and Precision Planting's eSet setups) with 5 different seeding rates (49383, 59259, 69136, 79012 & 88889 seeds/ha) and 4 ground speed treatments (6.0, 7.0, 8.2 & 9.4 km/hr) for a total of 20 treatments. The left half of the planter was similar to the other experiment, each replication contained all 20 treatments with strip planting (one planter pass represented an individual treatment) implemented for each ground speed. Seeding prescription (Rx) maps were generated in AgLeader's SMS Advanced software and exported for the proper display. Figure

2 presents the Rx map with seeding rates randomized within each replication. All treatments were randomized and replicated four times for a total of 20 treatments. At the center of each plot, seed spacing and plant population was collected on the 4 middle rows (rows 2 and 3 were John Deere Standard meters with rows 3 and 4 eSet meter setups) after emergence. In the region within each pass a seeding rate occurred, the location (documented using a GPS handheld device) with the length over the 4 center rows for a rate change was measured using a tape measure to the nearest 0.25 cm. Since ground speed was constant per pass, these distance measurements could be converted to a time for a rate change to occur. As-planted data consisting of plant population, seed spacing and meter performance was also recorded using 2 commercially available displays for both studies and analyzed for comparing planter performance based on actual field data.

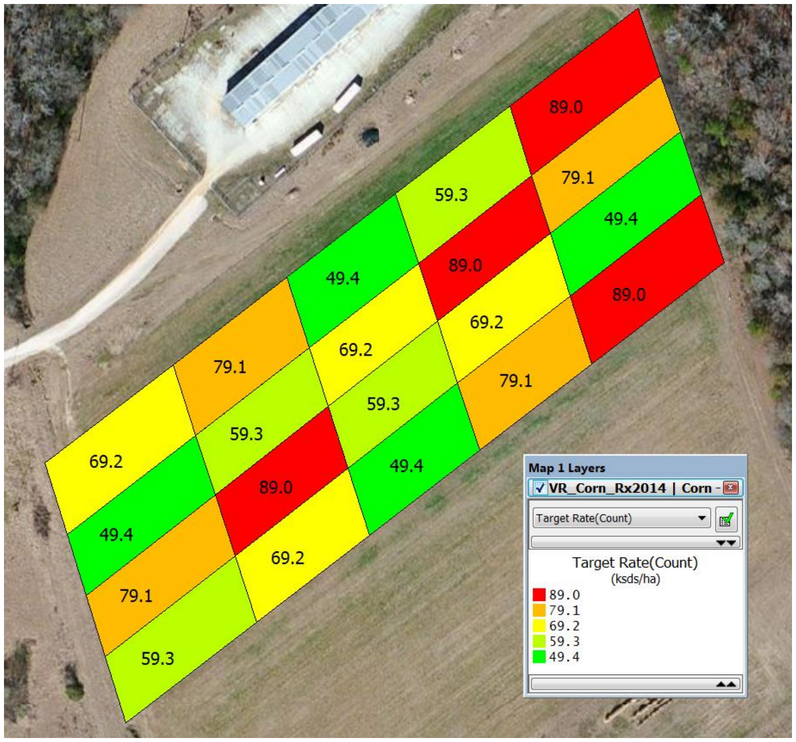

Fig. 2. Maize prescription (Rx) map illustrating seeding rate (units are 1000 seeds/ha) by replication for Field 3. Ground speed treatments were randomized within each of the replications and constituted full pass.

Data was summarized in Microsoft Excel. Emergence was the focus on this investigation so it along with final population and seed spacing were the main response variables. Analyses were conducted using both SAS and MiniTab. All comparisons were made at the 95% significance level ($\alpha = 0.05$). Of note, this study and associated results represent only one year but provided replicated data to understand planter performance.

RESULTS AND DISCUSSION

The downforce by seeding depth study offered insight to how these two planter settings affect final seeding depth. It should be remembered that on traditional row-crop planters, these parameters are usually set once and not changed by the operator for an entire field or several fields. Typically these parameters are only changed during planting if field conditions significantly change. For these two fields, final seeding depth was significantly different from the target depths of 2.5 and 5.1 cm (Table 1). The overall seeding depth for both fields was deeper than the target for the shallower treatment but shallower for the optimum 5.1 cm treatment. Overall variation in seeding depth was relatively small across each field with standard deviations of 0.2 cm or less. Statistical analysis showed that overall achieved seeding depth was significantly different between the two depth settings. Live population in Field 1 was significantly different between seeding depths with the shallower depth having only 93% emergence. The 93% emergence was not extremely low for these soil types but lower than past studies focused on maize that generated between 96% and 98%. Live population and thereby emergence (96%) were the same for Field 2. Field 2 tended to be planted deeper that Field 1.

Table 1. Overall mean seeding depth, live population and emergence (Emerg.) for Fields 1 and 2. Standard deviation provided in parentheses. Means with similar letters within a column are not significantly different (α=0.05).

	------------------- Field 1 -------------------			------------------- Field 2 -------------------		
TRT Depth (cm)	Measured Seeding Depth (cm)	Live Population (plants ha^{-1})	Emergence (%)	Measured Seeding Depth (cm)	Live Population (plants ha^{-1})	Emergence (%)
2.5	3.2^{b} (0.1)	60800^{b}	93^{b}	3.7^{b} (0.2)	62390^{a}	96^{a}
5.1	4.0^{a} (0.2)	62930^{a}	97^{a}	4.1^{a} (0.2)	62660^{a}	96^{a}

Table 2 presents a more in-depth view of final seeding depth and population by each downforce treatment. Seeding depth tended to increase with downforce except for the shallow depth in Field 1. In particular, the no downforce treatment at the shallow depth setting was significantly different in both fields. The only difference in live population and emergence was found in Field 1 at the shallow depth. Seeding depth (p=0.005) and downforce (p=0.046) were significant factors while an interaction existed between seeding depth and downforce (p=0.008). Therefore, final planting depth was affected by seeding depth and downforce. The existence of an interaction suggested that both might need to be adjusted on-the-go to maintain the target planting depth across a field. An interaction between soil type and seeding depth also existed and was explained by the in-field variability. In terms of emergence, more variability occurred at the shallow depth with the no downforce generating the highest variability. Emergence was affected by all treatments and a depth*downforce interaction existed. Higher downforce at the lower depth provided more uniform emergence compared to lower downforce for the deeper depth which provided less uniform emergence. A comment on this result is that high downforce at the shallow depth provided better seed to soil contact which favors seedling emergence. In summary, downforce significantly influenced final planting depth but results from this study suggested the difficulty in using only 1 depth and down force setting to maintain the target seeding depth in maize.

Table 2. Summary of seeding depth, live population and emergence (Emerg.) for Fields 1 and 2 which were planted at a population of 65,200 seeds ha^{-1}. Standard deviation provided in parentheses. Means with similar letters within a column are not significantly different (α=0.05).

		------------- Field 1 -------------			------------- Field 2 -------------		
TRT Depth (cm)	Downforce Setting	Seeding Depth (cm)	Live Population (plants ha^{-1})	Emerg. (%)	Seeding Depth (cm)	Live Population (plants ha^{-1})	Emerg. (%)
2.5	None	2.8^{d} (0.1)	59290^{b}	91^{b}	3.4^{b} (0.2)	61590^{a}	94^{a}
	Low	3.4^{c} (0.1)	61230^{ab}	94^{ab}	3.8^{a} (0.2)	61740^{a}	95^{a}
	Medium	3.3^{c} (0.2)	60810^{ab}	93^{ab}	3.8^{a} (0.1)	63090^{a}	97^{a}

	High	3.2[c] (0.2)	61860[ab]	95[ab]	3.9[a] (0.2)	63120[a]	97[a]
5.1	None	3.8[b] (0.1)	63120[a]	97[a]	4.0[a] (0.2)	63330[a]	97[a]
	Low	3.9a[b] (0.2)	62670[a]	96[a]	4.1[a] (0.2)	61950[a]	95[a]
	Medium	3.9a[b] (0.2)	62910[a]	96[a]	4.1[a] (0.2)	62370[a]	96[a]
	High	4.2[a] (0.1)	63030[a]	97[a]	4.1[a] (0.1)	63000[a]	97[a]

An additional result from Field 1 and 2 included that the primary factor driving emergence was soil moisture content. Results indicated that in-field, soil moisture variability significantly affected emergence; higher moisture content generating lower emergence. This result reinforced the need to not only understand processes in play at planting time but develop technologies that would enable to better manage this variability and improve planting performance. The ability to place seeds at the target planting depth and at the correct population ensures that maximum or near maximum yield potential exists from day 1.

Results for Field 3 indicated that planter field performance significantly varied for the two types of metering units; John Deere Standard and Precision Planting eSet meter setups. In general, the coefficient of variation (CV) of seed spacing increased with meter speed. Overall, the eSet meter setup performed better than the Standard John Deere meter setup exhibiting more uniform seed spacing over the 20 different meter speeds. The CV of seed spacing was 31% or higher for meter speeds above 25 rpm for the Standard John Deere meter setup with a maximum of 38% above this rpm. The plant spacing CV for the eSet meters was only higher than 31% for meter speeds above 28 rpm with a maximum of 34%. The eSet generated standard deviation of seed spacing between 3.8 and 6.6 cm with a majority under 5.1 cm across all treatments. Conversely, standard deviation of seed spacing ranged between 4.3 and 6.6 cm with only half under 5.1 cm for the Standard John Deere meters. Results indicated that planter performance was dependent on meter speed. Lab results using a meter test stand in conjunction with this field data demonstration that meter performance can sharply degrade at higher meter speeds (> 38 rpm) for both meter setups. Further, emergence was lowest (94-95%) for the highest seeding rate of 88,960 seeds ha^{-1} regardless of ground speed for both meter setups. The emergence for all other seeding rates was between 96% and 99%. Therefore, both the type of seed metering unit and meter speed (dependent on ground speed and seeding rate) can impact planter performance in terms of variability in plant spacing.

The variable-rate seeding results in Field 3 revealed the distance to make a rate change (e.g. response distance) was 2.0 m or less regardless of the magnitude in the rate change and ground speed. Converting the distance values to seconds indicated the response time for the variable-rate system was 1.0 sec or less. No significant difference was found between the rate transition time for ground speed (Table 3) or magnitude in the rate transition. The only small trend was as ground speed increased, the rate transition time decreased which makes sense since the distance measured in the field for a rate transition was consistent among treatments. No interaction existed between ground speed and the magnitude of the rate transition whether increasing or decreasing. Overall, this variable-rate seeding technoology was considered quick and consistent. This feature is desirable for a VR planter since this response minimizes rate change errors between management zones.

Table 3. Mean time for making a seeding rate transition by ground speed with standard deviation presented in parentheses. Means with similar letters are not significantly different (α=0.05).

Ground Speed (km h^{-1})	Rate Transition Time[1] (sec)
6.1	1.0[a] (0.2)
7.1	0.9[a] (0.2)
8.2	0.7[a] (0.1)
9.5	0.8[a] (0.2)

Table 4. Mean time for making a seeding rate transition based the magnitude of the rate transition with standard deviation presented in parentheses. Positive rate transition values indicate an increase in rate whereas negative represent a decrease. Means with similar letters are not significantly different (α=0.95).

	Magnitude in Rate Transition Increment / Decrement (seeds ha^{-1})							
	-39,540	-29,650	-19,770	-9880	9880	19,770	29,650	39,540
	---------------------------- Rate transition time (sec) ----------------------------							
Mean (Std Dev)	1.0[a] (0.2)	0.8[a] (0.2)	0.8[a] (0.2)	0.8[a] (0.2)	1.0[a] (0.2)	0.9[a] (0.1)	0.8[a] (0.2)	0.7[a] (0.1)

For discussion of as-planted data two figures were generated to point out differences between actual planted data versus prescription (Fig. 3) and the VR display created as-planted data (Fig. 4). One note of the actual as-planted is that no VR was performed during this pass and omitted for this analysis. Comparison of the as-planted data revealed first that a delay existed between when a rate transition occurred and the boundary of the management zone. The direction of travel, East-to-West versus West-to-East, generated different delay distances with the West-to-East being about half. The average delay distance West-to-East passes was 3.8 m with a maximum of 5.5 m at one transition while the East-to-West was on average 7.7 m and a maximum of 13 m. During an individual pass, the delay distance was consistent. This delay can be corrected with the look-ahead feature within the display but must be known to the operator in order to precisely set. The data acquisition (e.g. actual) generated as-planted map supports the above results in a quick rate transition (abrupt color changes) versus the display generated map. Comparison between the Rx and Actual As-Planted (Fig. 3) indicates that once a population was achieve by the VRS technology, performance was good for at least meeting the target population. Differences also existed between the estimated applied or planted population in some areas. However, while global trends existed between the actual and display as-planted maps (similar color regions between the two maps) illustrated differences between these layers and that the polygon representations were averaged values. The concern is that while global trends (highs and lows) in estimated planted population tended to exist, the map does not provide true spatial detail on population of planter performance as reflected in the actual as-planted map. In-cab observation of the display feedback by the operator and research assistant indicated good planter performance but the as-applied map suggested much more variability in planted population. Similar observations were made when including the second display as-planted data. Neither of the display as-planted maps provide detail details on when rate transitions actually occurred and were not reflective of the actual as-planted map making it difficult to make setup adjustments within the VRS technology. Therefore, disparity existed between display feedback and the resulting as-planted data which most likely was due to the averaging routines within the VRS technology and spatial representation (e.g. polygon). Further investigation is needed to understand the quality of as-planted data generated by other displays but these results emphasize that more detailed maps are required to support VRS in order to conduct the proper implementation and analysis. Field collected population and seed spacing within plots and regions where rate transitions occurred support the actual as-planted map created from the data acquisition system was reflective of the final population. Quality as-planted data reflecting details of planter performance will be most needed in the Southeast US where in-field soil variability can be considerable.

Fig. 3. Side-by-side comparison between the prescription (Rx) map versus the actual as-planted map based on the population information collected using the Biosystems data acquisition system. All maps created using AgLeader SMS Advanced software with units in 1000 seeds ha^{-1}. Note that the northern most pass was not included in the analysis since it represents a uniform rate.

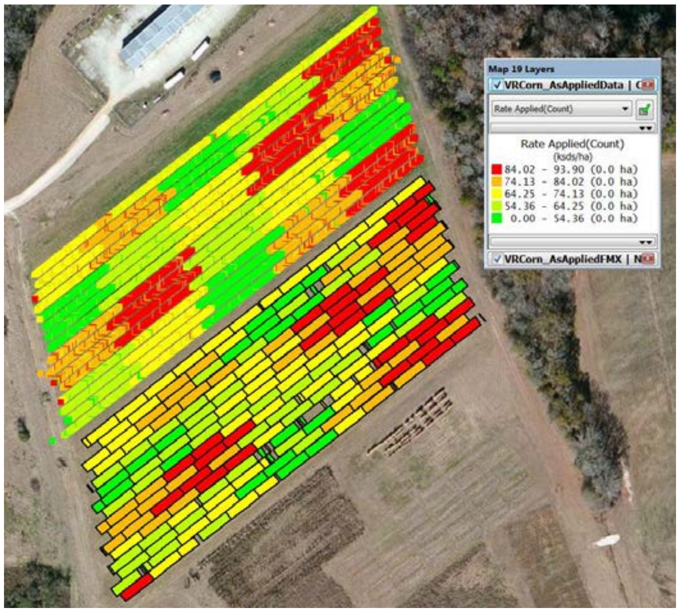

Fig. 4. Side-by-side comparison of as-planted data generated by the data acquisition system (North side and represented by point data) and one of the in-cab displays (South side represented by polygons). Units are 1000 seeds ha^{-1}. Note that the northern most pass was not included in the analysis since it represents a uniform rate.

In summary, while these experiments represent only one growing season, they highlight the impact of adjustable planter parameters that influence final population, seed spacing and ultimately plant emergence. These all need to be considered within a VRS program since planter performance is important to implement this type of seeding strategy. Results suggested the difficulty in using only 1 planter setup across soil types to maintain a target seeding depth in maize and that as downforce increased so can seeding depth. Actual planting depth was affected by the planter depth setting and downforce which makes sense but difficult to manage by operators when moving between fields or especially within an individual field. The absence of detail to these parameters can cause off-population, variation in seeding depth and deviation in seed spacing within seeding zones thereby negating the purpose of VRS and ability to properly evaluate. Variable-rate technology (VRT) has improved over the years with quick rate changes provided today. This study indicated delayed rate transitions which was different depending upon the direction of travel. This difference can be corrected through use of the look-ahead feature within the in-cab display setup in order to shift the rate change to the management zone boundary. Planter performance through current precision ag displays providing real-time population, singulation and other planting parameters, has helped to improve the quality of planting in the Southeast US. However, precision ag practitioners and seed companies providing VRS services must be aware to have the correct planter and technology setup to ensure success of implementation but also proper evaluation. The quality of as-planted data is vital as the Big Data evolution develops in agriculture. Results of this study highlight the need for improvement in as-planted data layers so they accurately reflect in-field seeding parameters such as final population. It may be necessary that as-planted data provide more information than just population to support VRS in maize here in the Southeast US due to in-field variability. Quality of as-planted data is needed as farmers rely on data management services to help drive decisions about input and machine management. Accurately documenting factors which influence emergence such as live population, seed spacing and depth through as-planted data help to ensure that proper decisions are made when evaluating VRS or other on-farm trials related to maize.

CONCLUSION

Results from this investigation indicated that final seeding depth of maize was impacted by both the planter depth setting and downforce applied on the gauge wheels. Final seeding depth did not equal the target depth for both Fields 1 and 2. Maize emergence was affected by both target planting depth and downforce in Fields 1 and 2. More variability in planting depth was measured at the 2.5-cm treatment compared to the 5.1-cm depth treatment. Final yield for both fields was most influenced by soil type which was expected since these fields had different yield potential for maize. In Field 3 where VRS was implemented, the time to make a rate change (e.g. response time) was less than 1.0 sec regardless of the magnitude in the rate change and ground speed. No trends existed for the time to make a rate change as ground speed and seeding rate varied indicating quick and consistent performance of the VRT used on this planter. However, a delay or lag was observed when a rate change occurred when crossing a management zone but varied depending up travel direction. The delay was 7.7 m when traveling East-to-West versus 3.8 m for West-to-East. Therefore, the correct planter and display setups must be used including defining the GPS location relative to the seed meter and entering the right look-ahead time within the display. Improper setup can impact final maize population and rate changes can initiate before or after the preferred MZ boundary. Significant differences were found between the two different metering technologies evaluated. The eSet meter setup provided a more consistent and better quality of seed metering in terms of singulation and seed spacing. Overall, the quality of seed metering degraded regardless of meter type at higher meter speeds (> 38 rpm) with this aspect not clearly indicated at times in the as-planted maps. The as-planted maps from the two commercial systems provided general representation of the planter population across the field but did not reflect the correct location of rate changes or did they take into consideration the actual planter performance when comparing to the final, emerged seed spacing. This study recommended that operators need to ensure the correct planter and display setups in order to achieve needed seed placement performance to support variable-rate seeding. In conclusion, implementing VRS in maize needs to consider the setup of the VR planter and technology to maintain desired seeding depth and final emergence while as-planted data must be improved and possibly include other parameters such as downforce and seeding depth.

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