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Development of an electro-mechanic control system for seed-metering unit of single seed corn planters Part II: Field performance

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ABSTRACT

Using single seed planters is important for a uniform distribution of plant growing area. Seed metering units of planters receive their motion from the drive wheel pass through various transmission members such as the chains, gears, shafts and belts. While the planter is being operated, the transmission system of the machine and drive system of the seed metering units naturally push the driving wheel. Because of this effect, the wheel experiences a loss of mobility or some sort of slipping. Consequently, all seed metering units are being affected due to the common mobility transmission system and changes in the desired plant spacing occur. In order to overcome these negativities, an electro-mechanic drive system (EMDS) alternative to classic driving system (CDS) was developed. Detailed information regarding the system design and laboratory simulation results of EMDS were provided in Part I of this study. In this part, it was aimed to investigate the effect of EMDS on the planting quality (plant spacing uniformity, variation among rows) and operational parameters (fuel consumption and negative slippage) in the field and compared with the CDS. While the quality of feed index (I_{qf}) 90.63%, multiple index (I_{mult}) 0.94%, missing index (I_{miss}) 8.44% and precision index (I_p) 17.63% were obtained in trials performed by the EMDS, I_{qf} 88.13%, I_{mult} 2.50%, I_{miss} 9.38% and I_p 17.81% were found in trials performed by the CDS. Plant spacing uniformity in the EMDS was found as "good" while it was "moderate" in the CDS, according to related criteria. Plant distribution uniformity in the EMDS were better than the CDS. Furthermore, the experimental plant spacing values obtained by the EMDS were closer to the theoretical (set) value than the values obtained by the CDS. The negative slipping in the planter's drive wheel was found as 1.33% at trials with the EMDS while it was 6.79% with the CDS. When the EMDS used in the field operations, it provided approximately 22% fuel saving compared with the CDS. The results promise that the developed system can be used as an alternative to the CDS for single seed planters. However, in order to provide a complete mechanical rapport between the EMDS and the planter, future studies, various structural improvements in the seed metering unit designs and optimization of the seed plate thickness, number of holes and connection methods may be required.

1. Introduction

Besides its significance in the human diet and as livestock feed, corn has lately emerged as an energy plant as well and it is being cultivated almost all around the world. Corn, for green and seed production, comprises approximately 186 million hectares of farmland in the world, which is approximately 26% of all the grain planted land in the world (FAO, 2014). Pneumatic precision planters are being used in most of these areas to plant corn. Using pneumatic precision planter is important for a uniform distribution of living area for the plants in the field as well as regarding the plant emergence duration (Karayel, 2009; Karayel et al., 2004; Scott A. Staggenborg et al., 2004). Furthermore, machinery usage is also important in eliminating competition for nutrients and water between the plants during the cultivation period and in decreasing loss of yield (Cay et al., 2017). In precision planting, it is imperative to put the seeds one by one in an accurate way in the desired spacing. Within this context, while the seeding norm adjustment in the pre-machinery planting period was done in "kg/area" ratio, lately the "number of seeds/area" ratio is preferred. Especially the number of seeds that needs to be disturbed in a unit area for row crops (number of seeds/area) is being used as a catalogue specification for a seed. For example, for corn varieties: Bora:7500–8000, Hido: 9000–10,000, Shermal:8000–8500 plants/da; for sunflowers Oliva CL:5000–5500, Siena: 6000–7000 plant/da. The best way to ensure this is to suitably operate the seed metering unit which is the key formula on the planter. Because seed metering unit directly affects the seed distribution uniformity (Li et al., 2015; Önal et al., 2012; Yazgi and Degirmencioglu, 2014). Throughout the historic development of this machinery, seed

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Fig. 1. A view from field trials and components of drive system 1: control panel, 2: electronic drive unit, 3: DC motors.

Table 1
Limit values of performance criteria for precision seeding (Aykas et al., 2013; Önal et al., 2012).

I_{qf} (%)	I_{mult} (%)	I_{miss} (%)	Classification
> 98.6	< 0.7	< 0.7	Very good
> 90.4 – 98.6	≥0.7 to < 4.8	≥0.7 to < 4.8	Good
≥82.3 to ≤ 90.4	≥4.8 to < 7.7	≥4.8 to < 10	Moderate
< 82.3	> 7.7	> 10	Insufficient

Table 2
Results of plant spacing uniformity indices.

Drive system	z_t (cm)	Z_e (cm)	I_{qf} (%)	I_{mult} (%)	I_{miss} (%)	I_p (%)	Evaluation
Electro-mechanic	24	24.02	90.63 ns[1]	0.94 ns	8.44 ns	17.63 ns	Good
Classic (Chain-sprocket)	24	26.97	88.13 ns	2.50 ns	9.38 ns	17.81 ns	Moderate

Tukey test: [1]ns no statistical difference in column.

metering unit has been the single unit that was most popular as a subject of improvement. However, studies on mobilizing the seed metering unit have been fairly limited up until recent times. The motion that the planters receive from the wheel pass through various transmission members such as chains, gears, shafts and belts to reach the seed metering unit. In the meanwhile, negative effects of the friction, slipping or tyre pressure that is created between the ground-wheel and the soil becomes inevitable (Iacomi and Popescu, 2015; Liang et al., 2015). In field conditions, while the planter is being operated, the transmission system of the machines, their transmission shafts and drive system of the seed metering units naturally push the driving wheel and as a result of this push, the wheel experiences a loss of mobility or some sort of slipping. As a consequence, all seed metering units are affected due to the common mobility transmission system and changes in desired seed/plant spacing occur.

Aykas et al. (2013) and Yalçin et al. (2013) used four different planters for corn and three for sunflowers. They determined a negative slipping rate of up to 8.77 and 8.28% respectively for the driving wheel of the machine. It was stated in the same studies that seed spacing uniformity values for all machinery were at "*insufficient*" and "*moderate*" levels and it was also put forth that the drive and transmission members of the planters should be manufactured at a higher quality and that they should be improved in general.

As mentioned during the first part of this study, systems that would be alternatives for mechanic driving systems were researched in recent years. For example; Kamgar et al. (2013) and Liang used mechatronic drive systems to increase the efficiency of the precision planters, while Iacomi and Popescu (2015) developed a system with electronic solenoid valve. In addition to these, Ovidiu et al. (2013) used an e-drive driving system and He et al. (2017) used an electric-driven control system to test the performance of the planters. Most of the studies conducted on alternative driving systems are in laboratory testing stage (Yang et al., 2015). In addition, the performances of the planters were only tested under laboratory conditions during majority of the conducted research. In such studies, the seed distribution uniformity obtained under laboratory conditions was used as a reference to estimate the seed distribution uniformity under field conditions. Therefore, there is very limited research on the field experiments of the planters. Panning et al. (2000) conducted using sugar beet seeds in laboratory and field conditions, it was identified that the uniformity obtained through sugar beet seeds under laboratory conditions were as good or better than the ones obtained under field conditions and that laboratory and field experiments can be used to identify the development needed parts of planter and seed metering unit. Recently conducted research (He et al., 2017; Yang et al., 2015) are clear indicators that studies on components of the planters and especially on driving and control methods of seed metering unit are still continuing. From another perspective, no study that examine the variation between the operational specifications of the newly developed driving systems of planter, such as fuel consumption and slippage and the seed metering units. Therefore, besides determining the planting quality specifications while using newly developed driving systems in field conditions, examining various operational specifications (fuel consumption, slippage) remain an important topic to be investigated.

This study is composed of two parts and in this second part of the study, it was aimed to investigate the effect of electro-mechanic control and drive system on the planting quality (plant spacing uniformity, variation among rows, fuel consumption and negative slippage) in the field condition. Design and laboratory performance of this system were evaluated in the first part of the study (Part I).