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Original Research Article

Preliminary Field Evaluation of Seed-Drilling Machine Trailed by a Tractor with Autopilot System

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Abstract: Seed drilling is one of the steps in agricultural operations that always needs great attention as it will eventually affect crop production. In a mechanized seed drilling, the quality of operation is measured by precision planting of seeds or seedlings in the rows. This study was conducted to evaluate a seed-drilling machine trailed by a tractor equipped with autopilot system. This machinery system was tested for planting corn on tilled soil. The tractor's operating speeds were set at three levels, i.e., 3.4 km/hr, 4.2 km/hr, and 5.5 km/hr. The effects of these different speeds were investigated towards numbers of seeds per hole, plants distance, and seedlings damage. Field capacity and average heart rate of tractor operator during conducting the operation were also measured. The findings showed significant differences between the operating speeds towards the numbers of seeds per hole and field capacity. Also, the observation showed that the operating speeds and field capacity had a close relationship. The same situation also happened between the operating speeds and average heart rates of operator. The operating speed of 5.5 km/hr was the best speed for achieving the highest field capacity, while the operating speed of 3.4 km/hr was highly recommended if seeds use efficiency become a preference. Generally, this study has successfully given introductory exploration for the potential use of tractor with autopilot system in seeds drilling operation for Malaysia's cash crop.

Keywords: Tractor; autopilot system; seeds drill; heart rate; mechanization

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1. Introduction

Farm mechanization has been known for its role in giving better ways of doing various farm works. Seeds drilling operation is one of the examples of practical mechanization application in farm works. Mechanized drilling using a seed drill machine has become a popular method in seed drilling operation because it increases the field efficiency, reduces labor usage, and eventually increases the yield. In the countries that applied mechanization in their agricultural operations, mechanized seed drilling is commonly used to plant various cereal grains crops in the field.

Various seed drill machines have been developed to assist the seed drilling operations for cereal grains crops. Generally, as grouped by Hunt and Wilson (2016), three types of seeding machines are widely used by farmers, i.e., small-grain seeding machines, furrow openers-small grain, and row planters. The sizes of machines are also varied according to the sizes of farmland. Seeding is a predominant operation of cereal grain crop planting. Srivastava *et al*. (2006) said that a new crop's growth begins with planting a seed or transplanting a seedling. Therefore, a planter or seed drill machine can exert a strong influence on the rate of germination of seeds. Kepner *et al*. (1978) defined that seeding or crop planting operations involve placing the seed in the soil at a predetermined depth, random scattering or dropping of the seeds on the field surfaces, or setting plants on the field. Thus, to conduct these operations, Deere & Company (1981) added that a planter or seed drill machine must have essential components such as furrow opener, seed metering, seed placement device, seed covering, and seedbed farming. A tractor is used to trail the machine to plant the seeds and complete a mechanized seed drilling operation system.

Today, the evolution of the tractor has changed farm technology from low-tech mechanization to high-tech mechanization. The tractor has advanced from its original primary use to substitute human and animal power to the present design, which can be used for multi purposes farm operations with improved functionalities and capabilities. The present design of the tractor has extended its usefulness and efficiency for agricultural operations and other off-road uses. With its advancement of the design and features such as traction and power, hydraulic remote-control units, electronic sensing, control of machine performance, camera vision and Artificial Intelligence, Deep Learning have made the tractor becomes an essential element towards efficiency and productivity of agricultural operations (Van Henten, 2020).

Specifically, numerous models and makes of tractors are available to be attached with the seed drill machine. Even lately, in line with the advancement of Global Positioning Systems (GPS), tractors with autopilot steering system is becoming as one of the parts of precision farming tools. Such tractor technology has made many changes in crop production systems, included in the seed-drilling operation. Autopilot is one of the driving technologies to minimize human intervention through a tractor's hand-free driving (Trimble, 2015). This system steers the tractors precisely in line, and it is able to improve field efficiency in crop production, particularly cash crops production.

Several past studies have revealed the usage of a tractor with autopilot for crop production systems. Zobato *et al*. (2019) proved that a tractor with an autopilot steering system improves the quality of mechanical peanut sowing and digging operations in Brazil. In Brazil, Santos *et al*. (2018) studied the position errors in sowing peanut in curved and rectilinear routes using autopilot in Brazil. Previously, Ortiz *et al*. (2013) and Vellidis *et al*. (2014) also evaluated tractor use with autopilot for mechanical peanut digging in the United States. They claimed that the machine system could perform mechanical peanut digging with high precision and lower digging losses and consequently higher financial return. Lipinski *et al*. (2016) compared the tractor implement unit operated in a conventional method when the tractor was operated manually and autopilot-steering modes.

Although it has been introduced to the global farming communities over the past two decades, the tractor with an autopilot steering system is relatively new in Malaysian agriculture. Till now, none of the farming communities in this country uses the tractor for daily farm operation. Even field performances of the tractor with autopilot for infield operations are infrequently studied in Malaysia. Only Hamdan and Pebrian (2019) attempted to assess the suitability of autopilot-automated tractor in Malaysia's flat terrain conditions. However, their study was limited to assess the straight-line accuracy of tractor movement in the field without operating any implement. Someway, they mentioned that tractor with autopilot has potential for usage in Malaysian farming. Therefore, based on their findings, a further study on the preliminary field evaluation of tractor with autopilot system mounted with implement is necessary to be conducted. Thus, this study emphasizes a preliminary field evaluation of a seed-drilling machine trailed by a tractor with autopilot system in planting corn in Malaysian farmland. The findings can accelerate the implementation of agricultural technology advancement, particularly in the use of advanced farm machinery to improve the workers' productivity.

2. Materials and Methods

2.1 Field Selection and Preparation

The field evaluation was conducted at university farm in UiTM Melaka, Jasin Campus, Melaka, Malaysia. The soil in the area was tilled soil category, and its terrain was considered a flat land with slopes ranging from 0% to 0.5% (Weiss, 2001). Before the evaluation, the area was plowed in order to make it ready for seeding operation. A New Holland tractor TD5.75 at 55.93 kW (75 hp) engine size furnished with an autopilot system was used in this study. The autopilot consisted of Trimble® EZ-Pilot® Steering System and Trimble® FmX® Plus Application. The Trimble® EZ-Pilot® Steering System fitted onboard is a motor for operating an automated-steering wheel. Trimble® FmX® Plus Application is a computer display with autopilot application software to operate and control the system. A 5-rows seed drill SRC 5 implement was attached to the tractor for corn seed-drilling operation. The detailed specifications of tractor with autopilot system and seed drill implement are shown in Table 1, Table 2, and Table 3, respectively. During the field evaluation, the weather was cloudy; thus, it might affect the GPS signal's strength in the autopilot system.

Table 1. Specifications of tractor.

Section of Tractor	Components	Specifications
Engine	Number of cylinder/aspiration/valve	4/TI/2
	Emission level	Tier 3
	Capacity	3908 cm^3
	Rated horsepower-ISO TR 14396-ECE R120	56/75
	Rated engine speed	2300 rpm
	Max. Torque – ISO TR14396	298@1400
	Fuel tank capacity	110 litres
	Service intervals	300 hours
Hydraulic	Main pump flow	36 l/min
	MegaFlow^{TM} pump flow	48 l/min
	Steering and services pump flow (Mechanical shuttle/Hydraulic shuttle)	29 l/min
Remote valves	Type	Deluxe
	Max. no. rear valves	3
	Max. no. mid-mount valves	2
Linkage	Max. lift capacity at the ball end	3565kg
	Max. lift capacity through the range (610 mm behind ball ends)	2700 kg

2.2 Experimental Procedure

A completely randomized design (CRD) procedure was applied in the field evaluation. The testing area was divided into 12 experimental plots. Each plot was 20 m X 5 m size. Seeds drill implement was operated under three different operating speeds of a tractor that was equipped with an autopilot system. In the operation, the tractor gear was set-up at the 2nd gear position. The tractor speeds were set-up at 3.4, 4.2, and 5.5 km/hr or equal to the engine speeds, i.e., 1000 rpm, 1500 rpm, and 2000 rpm, respectively. Each speed was replicated four times. The selection of the operating speeds was made based on the findings of a preliminary study that was reported by Hamdan and Pebrian (2019). They mentioned that the straight-line accuracy of the autopilot tractor movement in the field was good at the said speeds.

The number of seeds per hole, plants distance and planted seedlings damage were measured as the effects of tractor operating speeds. The number of seeds per hole refers to the total number of planted seeds in a hole after completion of the operation. The plant distance was recorded using a measuring tape. Seedlings damage refers to the seedlings that might be damaged by the tractor when it conducts other operations such as spraying and fertilizing for crop upkeep in the same rows where the seeds were planted before. In other words, seedlings damage was determined by rerunning the tractor on the recorded tracks or routes, which have been previously saved by the GPS coordinates at the day of planting operation. To measure the seedlings damage, the tractor was run on the recoded tracks after the seedlings grown about one-month-old in the field. Seedlings damage parameter is essential to be investigated since its result can indirectly reflect the straight-line accuracy of the tractor's movement in the field. It is crucial to make sure a minimum seedlings damage when the tractor running on the same rows for other crop upkeep operations such as spraying and fertilizing. In the experiment, each measurement was carried out with four replications.

Table 2. Specifications of autopilot system

Aspects of Autopilot	Components	Specifications
Brand	Trimble	Steering System and Plus Application
System	DC power	Supplied by TM-200, 27 volts, 3.5 Amps
	Processor	1 GHz quad-core
	Storage	Primary embedded memory — 32GB
Mechanical	Dimension	312 x 214 x 45 millimeters (plus connectors)
	Weight	2.5 kg (5.5lb)
	Mount	4 M6 screws on 75 mm centers
Housing	Material	Magnesium
	Environmental rating	IP55
Connections	USB (1 side facing, one rear-facing)	USB 2.0
	Ethernet (Via TM-200)	RJ45 connector
	CAN (sources 5VDC)	RJ11 connector
	Port Expander (optional)	One port for CAN bus, I/O, and serial
	HDMI output	DVI connector
Temperature	Operation	0◦C to 65◦C
	Storage	-40◦C to 85◦C
LCD	Size	307 mm
	Touchscreen	Protective capacitive touch
	Resolution	1280 x 800
	Brightness (adjustable)	1000 candela/m^3
Front-facing camera	Type	Low light level, color
	Resolution	1.3 Megapixel

Besides that, field capacity of operation and heart rate of the operator were also recorded. The heart rate of an operator was purposely measured since it can indirectly indicate the operator's comfort. According to Nkurikiyeyezu *et al*. (2017), heart rate variability can predict people's thermal comfort status. In this experiment, the operator's average heart rate was recorded using a Polar RS800CX heart rate monitor (Polar, 2013) and expressed in beats per hour (bpm). The field capacity was calculated based on the actual average coverage rate by the seed drill and expressed hectare per hour.

Table 3. Specifications of seed drill implement.

Aspects of seed drill machine	Specifications
Model	SRC 5
Mainframe	Reinforcement Steel
Dimension	1015 x 4003 x 1295
Hopper material	Stainless Steel
Hopper capacity (L)	250
No. of rows	5
Seed discharging wheel	Mild Steel
Seed discharging wheel arm (mm)	1168
Seed discharging system	Chain & Sprocket
Balancing wheel (automotive wheel)	16.5/ 13 (2ply)
No. of moldboard (adjustable)	5
No. of seed metering device (aluminum)-independent	5
Seed metering devices drive shaft (stainless steel solid bar)	1
No. of the chute	5
Weight (kg)	280
3-Point linkage	Cat I/II
Power requirement (hp)	45-85

Fig. 1 shows the tractor-mounted seed drill machine used in the study. The SPSS software was used to analyze the data. Tukey's test was done to compare the mean values of the number of seeds per hole, plant distance, and seedlings damage as results of treatment. While, field capacity and average heart rate were averaged by using Microsoft Excel 2016 spreadsheet software.

Figure 1. Seed drill implement mounted on tractor with autopilot system is operating in the study area.

3. Results and Discussion

Table 4 shows quality of work of seed drilling assisted by different levels of operating speeds of tractor with autopilot system. Seed drilling under the operating speed of 3.4 km/hr placed 2 seeds/hole as the lowest mean numbers of seeds per hole when compared with those of operating speeds of 4.2 km/hr and 5.5 km/hr. The mean number of seeds per hole produced by the operating speed of 3.4 km/hr were significantly different than those of operating speeds of 4.2 km/hr and 5.5 km/hr. However, plant distance and seedlings damage as results of operating speeds of 4.2 km/hr and 3.4 km/hr were significantly different from that of the operating speed of 5.5 km/hr. It was observed that the performance of seed metering mechanism on the seed drill implements at operating speed of 3.4 km/hr was very well in regulating the placement of seeds in the soil. This condition contributed towards the lowest mean numbers of seeds per hole. It is consistent with Ormond *et al*. (2018) who mentioned that the seed-metering device operating at lower speeds had better performance in the seeding process.

Mean plants distances as shown in Table 4 were in the range of 51.08 cm to 65.25 cm. Generally, the plant distances were acceptable with Malaysian corn farming practices since the measured plants distances are within the range of 50 cm to 75 cm as recommended by the Lembaga Pertubuhan Peladang (Malaysian Farmers Organization) (2017). As mentioned earlier, seed drilling with the tractor at operating speed of 3.4 km/hr planted 2 seeds/hole, and it was the lowest numbers of seeds per hole among three levels of the tractor speeds. These numbers also meet the standard of Malaysian corn farming practices by the

LPP (2017) who suggested that the numbers of seeds per hole for acceptable practices should be ranged from 1 to 2 seeds per hole. Seed drilling with 3.4 km/hr operating speed can offer more efficient numbers of seeds planted in a field. However, Caldwell (2014) mentioned that choosing of corn seeds population to be planted in a field must consider seeds genetics, agronomics, and economics aspects. The number of seeds planted can be less or more depending on these aspects. Generally, the numbers of seeds per hole as outcomes of a drilling operation in this study were adequate on the Malaysian soils.

Meanwhile, mean seedlings damage at the operating speeds of 3.4 km/hr and 4.2 km/hr were significantly different from that of 5.5 km/hr. Generally, mean seedlings damage ranged from 9.51% to 14.32%, and the values were considered as significant damage. Deere (2016) said that the seeds damage when the tractor moving on the rows shall not be more than 2%. Particularly in this study, it was observed that high seedlings damage due to low accuracy of GPS of the tractor. The GPS in the autopilot system was not equipped with Real-Time Kinematic (RTK) system. The system relies on the built-in differential GPS only; therefore, the transmitted correction signal gives low precision and accuracy. Another factor that might also affect the seedlings' damages is the limited size of experimental plots to cater to the tractor's maneuverability with an autopilot system. Nonetheless, this factor cannot be avoided due to the limitation of farm size used in the field evaluation.

Table 4. Quality of work of seeds drilling assisted by different operating speeds.

Operating speed (km/hr)	Mean numbers of seeds per hole, (seed) *	Mean plants distance (cm)*	Mean seedlings damage (%)*
3.4	2^a	51.08^a	9.55^a
4.2	3^b	51.50^a	9.51^a
5.5	3^b	65.25^b	14.32^b

*means with the same letter are not significantly different at the 10% level

Table 5 shows field capacity of the operation increased with increasing operating speeds. The highest field capacity was obtained when the tractor running at the operating speed of 5.5 km/hr, while the lowest one was at the speed of 3.4 km/hr. Theoretically, these findings agree with Siemens *et al*. (2008) who stated that the operating speed is one of the factors affecting the field capacity of farm machinery operation in the field. The more speed a machine operates the same size as the implement, the more field capacity is obtained.

Table 5. Mean field capacity and average heart rate of the operator by different operating speeds.

Operating speed (km/hr)	Mean field capacity (ha/hr)	Mean average heart rate (bpm)
3.4	1.06	113.82
4.2	1.58	107.85
5.5	2.26	101.52

Conversely, Table 5 also indicates mean average heart rate of the tractor operator decreased with an increasing operating speed. The lowest mean average heart rate (101.52 bpm) was recorded when the tractor was operating at the highest speed (5.5 km/hr). Initially, the heart rate was higher (113.82 bpm) when the tractor was running with the lowest operating speed of 3.4 km/hr. This might be because the field evaluation began with operating the tractor at lowest speed (3.4 km/hr). Thus, the operator is utterly busy to make sure the tractor and seed-drilling machine run smoothly. This condition might affect his heart rate. However, gradually, when the machine was running smoothly, the operator was more relaxed; hence, his heart rate also declined. Referring to the Polar RS800CX manual (Polar, 2013), the range of mean average heart rate of an operator from the study (101.52 to 113.83 bpm) were categorized in very light activity. Therefore, seed drilling operation assisted by the tractor with autopilot falls into a very light activity. Conclusively, running the tractor at an operating speed of 5.5 km/hr can be a good preference because it contributes to the highest field capacity or work productivity and the operator's relaxed feeling as well.

4. Conclusion

Seeds drilling operation assisted by a tractor with autopilot system for planting corn on Malaysian farmland was preliminarily evaluated. The preliminary evaluation was based on the tractor's different operating speeds, i.e. 3.4 km/hr, 4.2 km. hr, and 5.5 km/hr. Generally, the machine system was able to perform the operation well, and the results were in the range of a good corn planting practice as suggested by the Malaysian Farmers Organization (Lembaga Pertubahan Peladang). However, the percentage of seedlings damage in rows was relatively severe due to the seedlings were crushed by a tractor as low accuracy of GPS on the system. Therefore, completion of the system with an RTK (real-time kinematics) positioning system is strongly recommended. It would help the autopilot system to provide a high accuracy and high precision for the tractor moving in the field. If the accuracy improved by adding the RTK system, so the operating speeds of 5.5 km/hr were the best operating speed. This speed contributes to better work productivity by giving the highest field capacity. Besides that, it also offers the operator a relaxed feeling by giving the lowest mean average heart rate. The tractor with an autopilot system can be a universal prime mover for various Malaysian farmland implements to suit I.R 4.0 era in agriculture. Its presence offers an enhanced comfortability to the tractor operator. Overall, the findings enrich the information for the usage of autopilot tractor for farming communities in Malaysia. Further comprehensive studies and field evaluations are recommended to evaluate the tractor with autopilot system on a larger farmland area and different type of crops.

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