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Determination of Efficiency of Lightened Guidance System on Agricultural Machinery: A Case Study on Fertilizer Broadcaster

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Abstract: Recently, intensive researches are carried out on tractor guidance system by the researchers. One of these systems which aim to ease for operators is lightened guidance system in agricultural applications. Basic elements of the lightened guidance system are GPS receiver and light bar. The system is to provide as a parallel tracking according to based reference track. The operator steers simply the vehicle manually, using the lightbar as a guide for staying on track. Therefore, uniformity at row spacing on field is provided by the lightbar. In this study, geographical coordinate data during the granule fertilization application by using a fertilizer broadcaster was collected and analyzed. Three different operators drove the tractor with and without assistance of lightened guidance system. The collected data in both situations were mapped by the ARCGIS 9.3 software. Then, mean row spacing and deviations from row spacing were determined. The efficiency of the lightened guidance system was tested for broadcast fertilizer treatment. While row spacing values with guidance system were changed from 1815.07 cm to 1824.53 cm, row spacing values without guidance system were changed from 1360.44 cm to 1880.12 cm for three operators. More uniform rows were obtained when the tractor (with fertilizer broadcaster) driven with the assistance of guidance system.
Key words: Precision agriculture, guidance system, fertilization

INTRODUCTION

Many agricultural operations such as tillage, fertilizing and spraying should be made equal-width parallel swaths on the field by the operators. To maximize field efficiency and crop yields, operators must drive accurately to avoid excessive overlaps or gaps in field coverage. It is important to minimize the area of unworked and double-worked land by driving the vehicle straight and at a constant interval in the field in order to achieve high efficiency and the optimum use of inputs such as fertilizers and chemicals (Hamada, 2009).

Visual guidance systems such as mechanical and foam markers have been used for some time to provide guidance to the applicator. But, a number of problems exist with these such as dissipation of the foam before the operator can use it for the next pass, the operator still needs to estimate by eye where to turn and line up alongside the foam from the previous swath (Buick, 1997). Also, wind can make the foam drift causing gaps or overlaps in applications, and the application must be done in daylight (Kohls, 1996). In addition to these problems, with increased machinery working widths, higher field speeds, and extended hours of operation, visual guidance systems have been rendered less effective (Ehsani et al., 2002).

Newer systems are available that use differential global positioning system (DGPS) signals to provide field guidance (Grisso and Alley, 2002). One of these systems is lightened guidance system named as light-bar. A light-bar provides visual guidance information to the operator, allowing the operator to make manual steering corrections (Trimble Navigation, 2005). This technology allows the user to map the field perimeter and have the guidance system automatically lay a set of parallel swaths between the boundaries. User inputs such as spacing between parallel lines and number of lines are usually required (Tyler, Roberts and Nielsen, 1997). After these calibrations are made, if the operator deviates from parallel tracks, the swath bar will visually and/or audibly respond so a correction can be made. This guidance system allows a trained operator to drive straight while spraying pesticides, applying fertilizers, working at night, and almost any other instance where there is a need to drive in a parallel track (Wilcox, 2000 and 2001).

For parallel swath guidance, the light-bar removes the foam drift problem, can make it possible for the operator to apply for longer hours, operate at night, and operate in foggy or snow conditions (Buick, 1997). It provides benefits such as increased yield from crops, reduced input costs due to overlap, increased speed of field operations, extension of the workday, greater flexibility in hiring labor, reduced driver fatigue and reduced fuel usage (Webb, 2004).

There are many benefits of the lightbar usage. But the scientific studies on guidance systems are limited. The aim of this study was to determine the efficiency of the lightened guidance system with using of the fertilizer broadcaster.

MATERIALS and METHOD

Materials

In this study, Magellan Promark 500 GPS receiver and GreenStar light-bar guidance system (John Deere Company, Moline, Illinois, USA) were used to determine the efficiency process with using the fertilizer broadcaster. Lightbar guidance system includes Starfire 300 GPS receiver and lightbar. technical data of the receivers are given in Table 1.

Table 1. Technical data for the receivers

Receiver	Measurement Method	Accuracy
Magellan Promark 500	RTK	< 10 mm
Starfire 300	DGPS	< 30 cm

A laptop was used to collect Magellan Promark 500 navigation data such as position and travel speed. Software was written to read and store navigation data. It was written in Visual Basic.NET programming language (Microsoft Corp., Redmond, WA, USA). Serialport object that places in Visual Basic.NET toolbox was used to read RS-232 communication port. Serial data cable that belongs to GPS receiver was used to provide two way communications between Promark 500 receiver and laptop. The communication speed was set 9600 baud rates. The arrangements belonged to the system of the GPS receivers, guidance system and computer is presented in Figure 1.

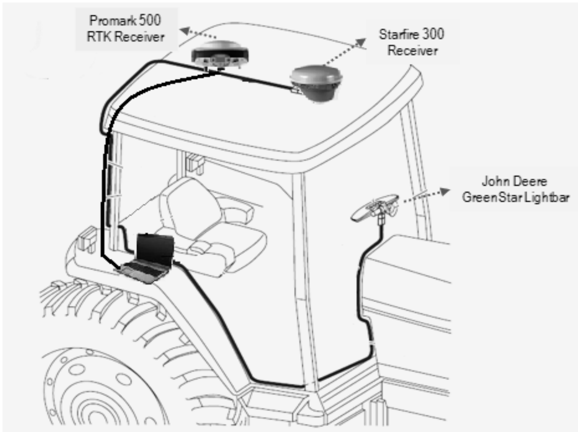

Figure 1. The arrangement of the receivers and light-bar (John Deere Corp., 2008)

In the field study the fertilizer broadcaster with two discs was used and its working width was 18 m. The applicated fertilizer (15-15-15, NPK) norm before maize seed operation was 400 kg/ha.

Method

Field tests were conducted in April 2011 at the fields of Batı Akdeniz Agricultural Research Institute, Antalya, Turkey. The experimental parcel sizes were 230 m × 550 m. The research area is located approximately 20 km from Antalya city center between the coordinates of 30° 53' 21.41"E, 36° 56' 29.43"N. The designed system was connected to a Massey Ferguson 3095D four-wheeled tractor. Developed system was tested on fertilization operation with the fertilizer broadcaster. The tractor was driven by three different operators who has experience of minimum 20 years. The operators steered tractor with and without lightened guidance system. Each test consisted of three parallel passes, and each pass was approximately 200 m long. The calibrated row spacing was 18 m. During the fertilizer treatments, the forward speed was measured as 7.5 km/h, approximately.

The lightbar calibration process is presented in Figure 2. The operator needs to define points A, B and C. Points A and B are used to calculate the heading and point C is used to calculate the track spacing, which is the distance (X) between the parallel tracks. Setup initial track as follows (John Deere Corp., 2008):

a. The system turns on the operator input indicator LED beneath the button (A) and waits for the operator input to set **A** point. Press button (A) to start heading calculation. Current position of point A is stored.
b. The system turns on the operator input indicator LED (flashing) beneath the button (B). The system checks that the operator has driven at least 3 m (9 ft 10 in.) then operator input LED becomes solid. The system waits for the operator input to set **B** point. Press button (B) when point **B** is reached. New A-B line is calculated and stored.
c. The system turns on the operator input indicator LED (flashing) beneath the button (C). The system checks that the vehicle heading is greater than 90 degrees from A-B line then operator input LED becomes solid. The system waits for the operator input to set **C** point. Press button (C) for less than 2 seconds when point **C** is reached. Vehicle position **C** and track spacing (X) are calculated and stored. System switches to Run Mode.

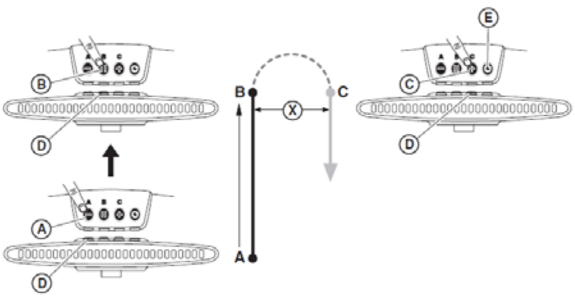

Figure 2. Light-bar calibration process (John Deere Comp., 2008)

Magellan Promark 500 GPS receivers send data such as latitude, longitude, speed, time, etc. with cable to other electronic devices via RS-232 serial port in NMEA 0183 format. NMEA 0183 is a standard protocol, use by GPS receivers to transmit data. All NMEA data is emitted as ASCII data. Latitude and longitude data received from a GPS receiver in the NMEA-0183 format is in unit's ddmm.mmmm, where dd equals degrees, *mm* equals minutes, and *.mmmm* is decimal minutes. For many purposes, position information in this format is more than adequate. However, when plotting position information on maps or carrying out supplemental calculations using the position coordinates, it can be advantageous to work instead with the corresponding grid coordinates on a particular map projection. One of the most widely used map projection and grid system is the Universal Transverse Mercator (UTM) system. UTM grid coordinates are related to geodetic coordinates, and indicates the corrections to be applied to grid distance and bearings to get the actual true quantities on the earth' s surface (Topakci et al., 2010). For this reason, data that received from Promark 500 GPS receiver was converted to UTM format, and stored to the database by the software. The interface of the developed software is shown in Figure 3.

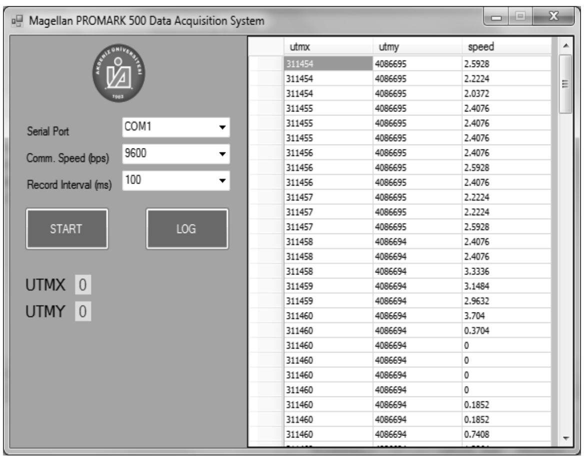

Figure 3. Developed software for GPS data collection

In this study, positioning data which was collected from Magellan Promark 500 GPS receiver was mapped by using ArcGIS 9.3 mapping software. For each operator, collected data with and without the lightened guidance system was mapped and distance between rows were measured on the map.

The study was arranged in a completely randomized design as a split-plot with two treatments and three replications for each driver. The lightened guidance system was tested with three operators to minimize the effect of operator on results. The main treatments were guidance system usage (using with and without guidance systems) and three drivers (A, B, C).

RESULTS and DISCUSSION

The tractor tracks (rows) on the experimental area were given in Figure 4. It is seen that row spacings formed by the lightened guidance assistance are much more uniform. The parallelism of the rows is better and longitudinal deviation from the nominal row center is lower when the lightened guidance system is used. But tracks in the turning points and beginning of the rows are not uniformed with guidance system. It is thought that tractor operators have not enough experiences on working with guidance system.

Figure 4. Tractor tracks in experimental field

Table 2. Mean, standard deviation and coefficient of variation values of row spacing using with and without guidance system

	With Guidance System Tractor Operator			Without Guidance System Tractor Operator		
	A	B	C	A	B	C
Mean row spacing (cm)	1815.07	1817.39	1824.53	1678.86	1880.12	1360.44
Standard Deviation (cm)	20.87	21.36	23.07	152.60	82.91	138.88
Coefficient of variation (%)	1.15	1.18	1.26	10.20	4.52	10.64

Table 3. Analysis of variance for standard deviation of mean row spacing

Source	df	Mean Square	F	P
Guidance System (G)	1	47771.605	21.793	0.001
Operator (O)	2	2062.456	0.941	0.417
G × O	2	2030.866	0.926	0.423

The mean row spacing, standard deviation and coefficient of variation of row spacing are given for each operator using with and without guidance system (Table 2). While row spacing values with guidance system are changing from 1815.07 cm to 1824.53 cm, that values without guidance system are changing from 1360.44 cm to 1880.12 cm for three operators. Minimum coefficient of variation was obtained when the operator A driven the tractor with the guidance assistance. The coefficient of variation of row spacing for the same operator (A) without guidance system is about 9 times higher. The standard deviation and coefficient of variation of row spacing was lower when guidance system used for all operators. More uniform rows were obtained when the tractor driven with the assistance of guidance system.

The results of the variance analysis are given in Table 3. While the effect of guidance system was significantly important ($P<0.05$), the effect of operator and guidance system × operator interaction was not important. The lightened guidance system gave similar results for all drivers.

CONCLUSIONS

The effect of lightened guidance system on the row distance uniformity while fertilization operation was tested. More uniform rows were obtained when the tractor (with fertilizer broadcaster) driven with the assistance of guidance system. The experiments were replicated with three different operators. The effect of operator on row uniformity was not important and the guidance system increased the row spacing uniformity for all drivers.

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