EVALUATION AND CONTRAST OF AN AUTO GUIDANCE SYSTEM OPERATING ON A SUGAR CANE HARVESTER IN BRAZIL

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ABSTRACT

The change on the harvesting sugar cane operation from the manual to mechanized cut increased the amount of sugar cane cut by the mill per day, but the operation increased the cane loss, which is left behind on the field. The purpose of this work was to contrast the accuracy achieved by an auto guidance system on the passes of a sugar cane harvest machine over the field, which was planted by a tractor guided by the system too, contrast the quality of the harvested product (mineral and vegetal impurities) and cane loss, when compared to the manual guidance method. The field test was conducted with two treatments: auto guidance and manual guidance; during two period of time: day and night; and four blocs per treatment: pass/row 1 to 4. Each GPS position recorded represented a single sample, which was used to calculate the error pass when compared with the planned pass. The statistical analysis was made with SISVAR software, calculating the Tukey test at 5% of significance. It was concluded that the use of the auto guidance system does not increase the machine operational efficiency on the mechanized sugar cane harvest operation, once its efficiency is guided by the sugar cane wagon. The mineral and vegetal impurities were the same for manual and auto guidance systems, likewise the sugar cane field loss. The use of auto guidance systems decreased the error of the machine over the planned row track.

Keywords: auto-guidance, GPS, sugar-cane.

INTRODUCTION

The change on the harvesting sugar cane operation from the manual to mechanized cut increased, initially, the cane loss which is left behind on the field and, nowadays, can reach 15%, besides the raise of vegetal and mineral impurity which are taken to the mill. Recently, precision farming techniques are being applied to decrease the costs involved with the ethanol production by the smaller use of agrochemicals and others agricultural inputs, contributing to a better energetic balance on the ethanol production based on sugar-cane. It is possible to optimize the agricultural mechanized system, decreasing the use of machines, based on the use of auto guidance system oriented by GNSS. According to Stombaugh et al. (2008), the most commonly used satellite-based radio-navigation system is the Global Positioning System (GPS), which is maintained by the United States Department of Defense; however, there are several other similar systems that are currently in use or development. The term Global Navigation Satellite System (GNSS) has been adopted to describe this family of satellite-based positioning technology. According to Stabilei & Balastreire (2006), the high cost of acquisition of a GNSS system has being delaying the progress of the use of precision farming techniques in Brazil. The market offers several GNSS receptor models, and in between then, models with differential correction based on Real Time Kinematic (RTK) which offers the biggest accuracy on the positioning in real time (Trimble, 2009). A huge benefit on the use of that system is the operational error reduction, error that can be occasioned by human interference during a mechanized operation on the field. According to Baio (2005), the use of a GNSS on a farm cannot be delimited by its use on a single operation, like spraying, but needs to be used as much as possible within an agricultural year, diluting its acquisition cost.

Balastreire & Baio (2002) showed that the relative positioning with a Differential GPS (DGPS) can be replaced by a GNSS which uses a mathematical equation (algorithms), very popular in South America. Therefore, these systems with algorithms cannot reach an accurated position, because it just increases precision. To Baio (2007), some agricultural operations require the highest accuracy possible that the common DGPS cannot offer, like on the mechanized sugar cane plant operation or mechanized sugar cane harvest operation, needing a RTK correction. The author also comments that the sugar cane agricultural segment in Brazil is increasing the investment on auto guidance system. Shockley & Dillon (2008) related that the auto guidance decreases the overlapping application on the field, increase the operational speed, allow a higher accuracy on the inputs application and increase the available time to finish the operation. Batte & Ehsani (2006) showed that the cost reduction gathered by the use of this technology is substantial. Even though, Cole et al. (2004) showed that static performance specifications of GNSS are not always indicative of dynamic performance.

The purpose of this work was to contrast the accuracy gathered by an auto guidance system on the passes of a sugar cane harvest machine over the field, copare the quality of the harvested product (mineral and vegetal impurities) and quantify the cane loss, when compared to the manual guidance method.

MATERIAL AND METHODS

The field evaluation was made on Campanelli Farm, located at São Jose do Rio Preto city, Brazil. This farm grows sugar cane to Guarani Sugar Cane Mill. The field work was done during the first week of august, 2009; it was not observed solar activity during this time, which could affect the GNSS accuracy. The number of available GPS satellites was always above five, during all tests.

A CASE sugar cane harvest machine was used on this test, model 7700, with an auto guidance Trimble, model AutoPilot, and with a RTK correction system provided via radio link. All passes were recorded by the Trimble monitor model FMX.

The field test was conducted with two treatments: auto guidance and manual guidance; during two period of time: day and night; and four blocs per treatment: pass/row 1 to 4. Each GPS position recorded represented a single sample, which was used to calculate the error of the pass when compared with the planned pass. The statistical analysis was made with SISVAR software, calculating the Tukey test at 5% of significance.

The methodology described by Balastreire (2007) was used to calculate the machine´s field efficiency and the operational field capacity. The data collected was the total time, maneuver time, refueling stops, maintenance, and the sugar cane wagon waiting time. These times were collected by a digital chronometer. The speed of the harvester machine was kept at 3,7 $km.h^{-1}$, this speed was chosen according to the sugar cane plant size and vigor on this field.

The field coordinates of the recorded row passes (sequenced points) where exported from AgGPS to the GIS (Geografical Information System) SSToolbox 3.8.0, where the data was manipulated and the row passes' maps were generated. By the use of this GIS, the field points coordinates were exported to Excel software, where the coordinates were converted to UTM (Universal Transverse Mercator), and the error's passes were calculated.

The methodology used to calculate the relative positioning accuracy was suggested by Stombaugh et al. (2008). They also distinguish between absolute and relative positioning accuracy. Absolute accuracy is the measurement regarding to a true reference position and relative accuracy is the measurement regarding to other navigation data records collected from the same receiver. The reference points were extracted from the poly-line representation of the reference track and projected into the localized coordinate system. The reference track to the field row passes test was given by the passes recorded by the GPS system during the mechanized sugar cane plant operation on the previous year. These points of the reference track were spaced 1 cm apart along the track path. Off-track error was calculated for each data point by finding the minimum distance from the data point to any of the points on the track (Figure 1). The straight line represents the shortest distance between the reference and the first pass auto guided. Since the reference trajectory was not represented by a continuous line but rather by a group of densely spaced points, the off-track error was slightly overestimated. Unless the data point was directly perpendicular to the closest reference point, the error would be slightly larger than the true perpendicular distance to the reference trajectory. This routine was done by an Excel macro. During the manual test, all monitors and GPS displays were hidden from the operator, who was the same for all tests.

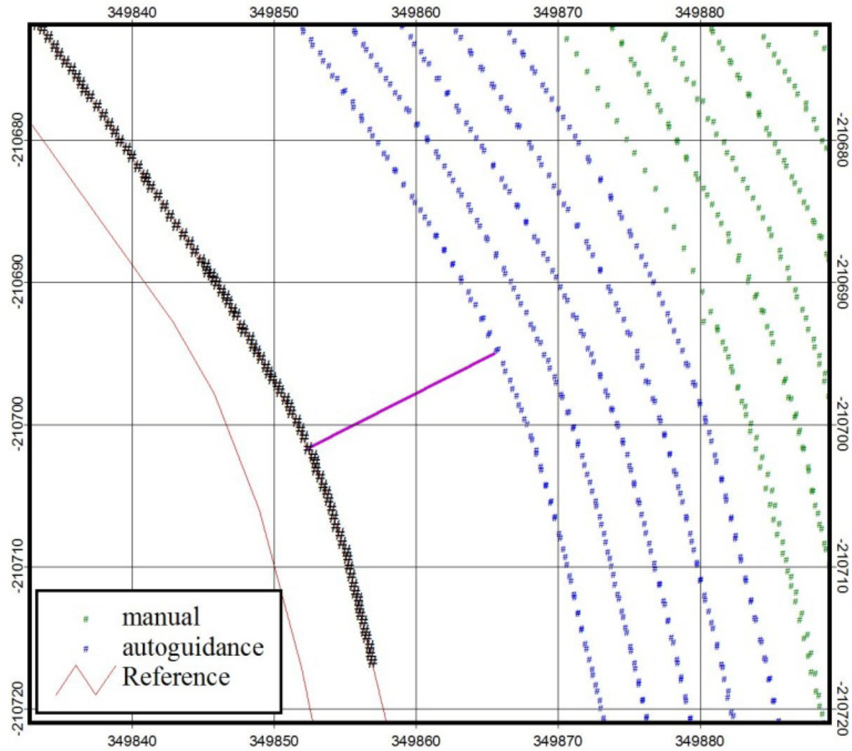

Fig. 1. Map illustrating the reference pass related to manual and auto guidance passes done by the harvester, operating in curves.

The mineral and vegetal impurity contrast between the treatments were made following the methodology suggested by Benedini et al. (2009), collecting vegetal samples from each sugar cane wagon which was sent to the mill's laboratory to calculate the impurity. The sugar cane loss was calculated according to the methodology suggested by the same author, where all parts of sugar cane left behind on the field by the harvest machine, besides sugar cane root, are collected in a sample and weighted.

RESULTS AND DISCUSSION

Table 1 shows the statistical Tukey test to the error comparison between the average of the treatments measured between the reference line and the recorded track line. It can be observed that the manual guided system got a higher error (0,183 m) when compared to the auto guidance system (0,039 m). According to John Deere (2009), GPS operating with RTK correction can reach 0,025 m of accuracy within 95% of the acquiring time; therefore, this accuracy was measured in statically conditions. To perform the harvesting operation with the auto guidance system assembled on the harvester machine, it is primordial that the agricultural system was planted with the auto guidance system on the tractor as well; otherwise, the harvester machine will follow the planned rows that will not match with the planted rows, passing over it.

According to Baio (2007), the irregularity of the spaces between the rows planted with sugar cane is the major cause of the cane destruction, which could grow up on the following year, but it is destroyed by the sugar cane harvester machine, decreasing the following yield.

Table 1. Tukey test error comparison between the average of the treatments, when the sugar cane harvester machine was guided by the manual and auto guidance systems.

Treatments	Period	Error[1]
		m
Auto Guidance	Day	0,052
Manual	Day	0,143
Auto Guidance	Night	0,026
Manual	Night	0,223
Auto Guidance - Total	Day and Night	0,039 B
Manual - Total	Day and Night	0,183 A

[1] Averages followed by the same letter on the column does not differ by the Tukey test at 5% of significance level. DMS (Minimal Significance Difference): 0,016.

The Table 2 shows the comparison between the quality of the harvested product (mineral and vegetal impurities) and sugar cane field loss. According to the classification suggested by Benedini et al. (2009), the sugar cane loss and mineral impurity average from the field samples can be classified as low, however, the vegetal impurity average was high (above 6%). It can be observed that the use of the auto guidance system did not decrease statistically the impurity of the sugar cane material sent to the sugar mill, likewise the sugar cane loss, which got statistically the same average for both treatments.

Table 2. Tukey test comparison between the average of the treatments to the mineral impurity, vegetal impurity and sugar cane field loss, when the sugar cane harvester machine was guided by the manual and auto guidance systems.

Treatments	Mineral Impurity	Vegetal Impurity	Sugar Cane Loss
	Average[1]	Average[2]	Average[3]
	kg.t^{-1}		t.ha^{-1}
Auto Guidance	6,81 A	87,41 A	3,69 A
Manual	10,21 A	63,49 A	3,84 A

PS: Averages followed by the same letter on the column does not differ by the Tukey test at 5% of significance level. DMS (Minimal Significance Difference): [1]5,59; [2]56,01; and [3]4,67.

From all machines times collected at the field during the day and night operations, it was possible to calculate the operational machine field efficiency (Table 3). The averages were very similar comparing the guidance method and the light condition, reaching 80%, and considered adequate, as proposed by ASAE (2000) to this kind of operation.

Table 3. Operational machine field efficiency (%) comparison between manual and auto guidance systems measured within the day and night periods.

Treatments	Periods	Operational Field Efficiency
Auto Guidance	Day	80,0%
Manual	Day	79,4%
Auto Guidance	Night	83,4%
Manual	Night	86,0%
Auto Guidance – Total	Day and Night	81,7%
Manual – Total	Day and Night	82,7%

Otherwise the quality of the sugar cane material harvested and sent to the mill was statistically the same, using or not the auto guidance system, the huge advantage of the use of auto guidance system oriented by GNSS systems are related to the increment on the accuracy of the passes in between the row tracks, avoiding the machine passing over the planted row. This characteristic brings, otherwise raising the initial financial investment, several undirected financial advantages related with the increment of the sugar cane life across the productive years, like the increment on the cane yield within the years by the reduction of the soil compaction.

CONCLUSIONS

The use of the auto guidance system does not increase the machine operational efficiency on the mechanized sugar cane harvest operation, once its efficiency is guided by the sugar cane wagon. The mineral and vegetal impurities were the same for manual and auto guided systems, likewise the sugar cane field loss. The use of auto guidance systems increases the field passes accuracy over the planned row track.

ACKNOWLEDGMENT

Special thanks to Campanelli Farm that provided all field test support, Santiago & Cintra as Trimble dealer and Guarani Sugar Cane Mill, who provided the sugar cane analyses.

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