AGRARIAN
OPEN ACCESS
e-ISSN: 1984-2538

Depth, coverage and spacing of the furrows in mechanized sugarcane plantation with planter and distributor in the day and night shifts

Profundidade, cobertura e espaçamento dos sulcos no plantio mecanizado de cana-de-açúcar com plantadora e distribuidora nos turnos diurno e noturno

Camilla Missio
Universidade Federal da Grande Dourados
E-mail: kmissio@hotmail.com
OrcID: https://orcid.org/0000-0001-8522-8263

Jorge Wilson Cortez
Universidade Federal da Grande Dourados
E-mail: jorgecortez@ufgd.edu.br
OrcID: https://orcid.org/0000-0003-1120-719X

Ana Karina Gurgel Barreto
Adecoagro Vale do Ivinhema
E-mail: abarreto@adecoagro.com
OrcID: https://orcid.org/0000-0001-5189-6351

Marcelei Daniel da Silva
Adecoagro Vale do Ivinhema
E-mail: msilva@adecoagro.com
OrcID: https://orcid.org/0000-0001-8651-7171

Egas José Armando
Eduardo Mondlane University, Maputo, Moçambique
E-mail: earmando24@gmail.com
OrcID: https://orcid.org/0000-0003-1983-3574

Abstract: Mechanized planting, is one of the main operations in the sugarcane production cycle that directly affects the longevity of the shoots, the crop yield and the profitability of the crop. Thus, this study aims to evaluate the furrow depth, furrow coverage and furrows spacing in a mechanized sugarcane plantation with a planter and a distributor in the day and night shifts of operation, using as statistical analysis quality control tool. In both shifts were sampled 30 points, where was collect data of furrow depth, furrow coverage and furrows spacing. The quality indicators of mechanized sugarcane planting are not influenced by the day and night shifts, and present values considered satisfactory when carrying out mechanized planting with a planter or distributor.

Keywords: Statistical Control Process. *Saccharum Spp.* Charts of Control.

Resumo: O plantio mecanizado é uma das principais operações do ciclo de produção da cana-de-açúcar, pois afeta diretamente a longevidade de soqueiras, a produção e a rentabilidade da cultura. Objetivou-se avaliar a profundidade, cobertura e espaçamento dos sulcos do plantio mecanizado de cana-de-açúcar com uma plantadora e uma distribuidora nos turnos diurno e noturno de operação, utilizando-se como ferramenta de análise o controle estatístico de qualidade. Para as variáveis profundidade, cobertura e espaçamento entre sulcos foi realizada amostragem em 30 pontos para cada turno (diurno e noturno). Os indicadores de qualidade do plantio mecanizado de cana-de-açúcar não são influenciados pelos turnos diurno e noturno e apresentam valores considerados satisfatórios ao realizar o plantio mecanizado com plantadora ou distribuidora.

Palavra-chave: Controle Estatístico de Processo. Saccharum Spp. Cartas de Controle.

Data de recebimento: 25/02/2021
Data de aprovação: 05/01/2022
DOI: https://doi.org/10.30612/agrarian.v14i53.13966

1 Introduction

Brazilian sugarcane production has been increasing in recent years, especially in the south-central region of Brazil, what accomplishes the states of São Paulo (4 357,142 thousand tons), Goiás 70,622 thousand tons), Minas Gerais (64,886 thousand tons) and Mato Grosso do Sul (46,940 thousand tons), with a total yield of 641,066tons of sugarcane (UNICA, 2018).

Among the operations involved in the sugarcane production system, the planting influences longevity leading to satisfactory germination and moisture holding, crop production, increasing the tilling of the deeper placed shoots, thus, yield increase, therefore, economic profitability. Thus, any decision taken at this stage influences the whole cycle process, by the other hand, the planting process stands out due to the high costs involved on it, which impact during an economic cycle of the five harvests, or five years of the crop management, before the renewal of the crop (Barros & Milan, 2010).

The adoption of mechanized planting benefits the operability of the mechanized assemblies what can increase the operational capacity, reducing the operational costs when related to the semi-mechanized planting, however, this requires more technical knowledge. Nowadays, investments in improving mechanized field operations in planting sugarcane during the day and night shifts is increasing, although, information on mechanized operations still incipient (Voltarelli *et al.*, 2013).

In this paper, we present the results of the analysis of the mechanized planting, which are characterized by high variability, related to the working shift, using statistical process of control (SPC). In order to improve quality and technical intervention, a good planning and management of the mechanized operations through statistical process control (SPC) or statistical control quality (SCQ) is essential, to contribute for the rationalization and reduction of input costs and improvements of the system (Chioderoli *et al.*, 2012; Cassia *et al.*, 2013; Silva *et al.*, 2013).

In this context, the statistical process control (SPC) has been applied in agriculture mechanization to identify critical factors related to the efficiency and effectiveness of mechanized operations, through the effective control of variables, limiting them in the acceptable standards (Noronha *et al.*, 2011; Melo *et al.*, 2013; Voltarelli *et al.*, 2015). Thus, the stability of agricultural operations can be verified, identifying if the instability or variability of the agricultural process occurred due to random (intrinsic) causes, or special (extrinsic) causes, which cause the process not meeting the established limits of control (Voltarelli *et al.*, 2015).

This study aims to evaluate the furrow depth, furrow coverage and furrows spacing in a mechanized sugarcane plantation with a planter and a distributor in the day and night shifts of operation, using as statistical analysis quality control tool.

2 Material and Methods

The trial was conducted in the Mato Grosso do Sul - MS, in a commercial area located at latitude 22º11’ S, and longitude 53º58’ O with elevation ranging from 312 to 376 m. The soil of the area is classified as Red Latosol, with an average field slope of 4.45% with a minimum of 0.023% and a maximum of 13.56%. The climate is considered as tropical Aw with summer rains, according to Köppen classification.

The mechanized planting of sugarcane, in the day and night shifts, was accomplished with a tractor-planter, composed by a tractor with power of 156.66 kW in the engine at 2.200 rpm, working in the 8th working gear and with an average displacement velocity of 5.5 km h^{-1}. The planting implement was a two-row chopping sugarcane planter, with a capacity of six tons of seedlings for planting, with spacing rows of 1.50 m (Figure 1). Then, for a better performance of the distributor, previous furrows opening operations were performed with a furrower of two hummingbird type furrows, with two polyethylene fertilizer boxes of 370 L capacity each. After that, was performed the distribution with a distributor of two conveyor belts at the bottom of the bucket, which takes the grinding wheels at the two conveyor belts driven by independent hydraulic circuits (controlled via monitor from the tractor cab), which deposits them in two planting furrows and the furrow cover mechanism of 6 flat concave disc with angulation adjustment , mounted on 3 sets of individual oscillating pantograph disc with 3 aligners tires working inside the furrows, directing the picker with 3 rollers oscillating angle grinders, 3 leveling devices fixed to each roller compactor. The seedlings used were cultivar CTC 14 and RB96 6928 and developed by the Sugarcane Technology Center (STC).

Thus, the data collection was set an area of 50 m x 1.50 m, where 30 points were evaluated in each shift, in the 24 hours after the mechanized planting was performed. At each sampling point, a distance of five meters from the furrow was evaluated, being excavated after the mechanized planting using a hoe (Voltarelli *et al., 2014)*.

The furrow coverage furrow and depth were obtained after the planting of the stalks in the furrows. A template was set at the edge of the furrows, then was measured

AGRARIAN
OPEN ACCESS
e-ISSN: 1984-2538

the distance from the grinding wheel to the template with the tape measure, determining the furrow coverage (Figure 1). Then, to determine the furrow depth, a furrow was excavated until finding the fertilizer and then measured the distance of the fertilizer to the template. Furthermore, was also measured the distance of the furrows from center to another center of two adjacent furrows.

Figure 1. Furrow coverage (a) and furrow depth in the mechanized planting.

Furrow coverage (a)

Furrow depth (b)

Once the variables were measured, the data was analyzed through descriptive statistic to identify the standard deviation, variance, coefficient of variation, minimum, maximum, asymmetry and kurtosis. Subsequently the data was submitted to statistical control process (SCP) to evaluate the quality of the mechanized planting, through the individual control charts that use three times the standard deviation as lower and upper limits of control and the specific limits defined by the producing unit (Table 1). If all the observations are within the limits of control, the process was considered stable, but when observations were outside the limits the process was considered out of control under the action of special causes of variation. The specific quality limits were established by the production unit aiming to the quality of the mechanized planting operation, being used in the control charts as specific upper and lower limits (Table 1).

Table 1. Specific control limits for the quality indicators defined by the production unit

Quality indicators	Low specific limit (LSL)	High specific limit (HSL)
FD	0.25	0.35
FC	6.0	10.0
FS	1.45	1.55

FD – furrow depth (m); FC – furrow coverage (cm); FS – furrow spacing (m).

3 Results

The data furrow depth and furrow spacing in the mechanized planting of sugarcane (Table 2) indicated a normal distribution, for both shifts, what was confirmed by the asymmetry coefficients and kurtosis coefficient near zero for planter and distributor. The furrow coverage data indicated a asymmetrical distribution for both shifts the planter, what was verified by the high values of kurtosis coefficient and negative values of the asymmetry coefficient.

The coefficient of variation of FD and FS (Table 2) showed a low value for both shifts. Moreover, FD and FC coefficient of variation for night shift at planter and only FC for night shift at distributor showed a medium variation coefficient (Pimentel Gomes, 2009).FC coefficient of variation for day shift showed a high value for planter and distributor.

Table 2. Descriptive statistics for furrow depth, furrow coverage, and furrow spacing attributes for the planter- distributor

Attribute	M	SD	V	CV	Min	Max	CA	Ck
Day shift – Planter								
FD	0.28	0.02	0.00	8.99	0.23	0.33	-0.27	-0.52
FC	8.20	1.95	3.82	23.78	0.00	10.00	-2.64	10.18
FS	1.53	0.06	0.00	4.31	1.38	1.70	0.23	0.31
Night shift – Planter								
FD	0.28	0.03	0.00	11.60	0.22	0.34	-0.38	-1.08
FC	7.96	1.54	2.37	19.34	6.00	10.00	-0.00	-1.47
FS	1.52	0.07	0.00	4.60	1.35	1.70	-0.08	0.77
Day shift – Distributor								
FD	0.27	0.02	0.00	9.08	0.23	0.30	-0.43	-1.56
FC	6.86	1.45	2.12	21.20	4.00	9.00	-0.89	-0.54
FS	1.49	0.03	0.00	2.27	1.43	1.55	-0.30	-0.97
Night shift – Distributor								
FD	0.29	0.02	0.00	8.93	0.23	0.33	-0.95	0.01
FC	7.70	1.44	2.07	18.73	5.00	10.00	-0.10	-0.66
FS	1.47	0.04	0.00	3.19	1.37	1.57	-0.19	-0.25

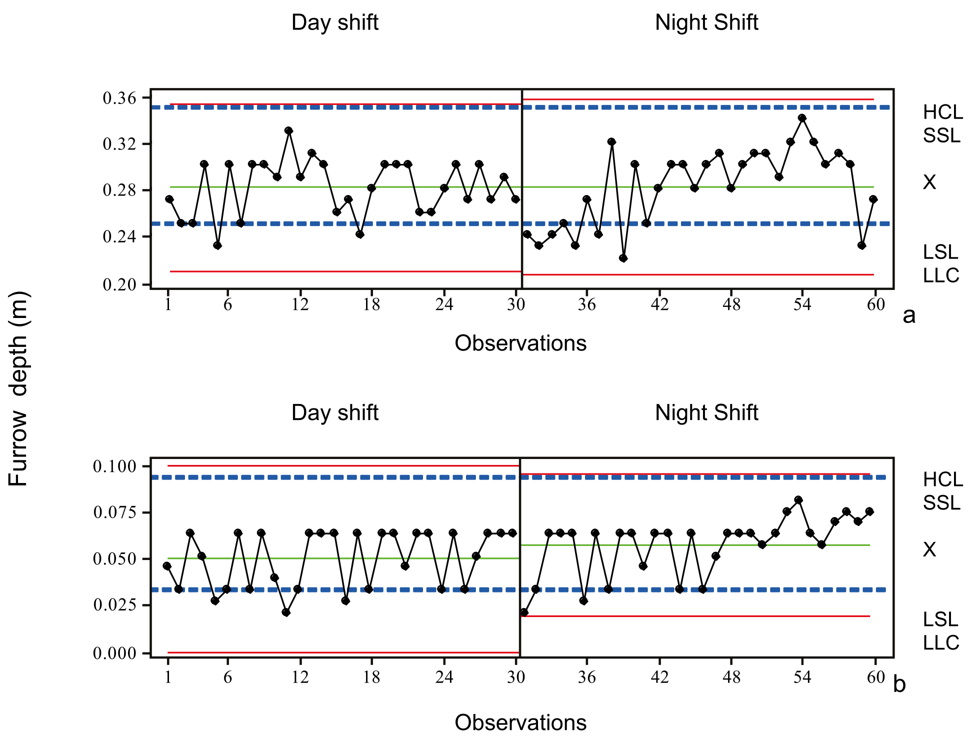
M – mean value; SD – standard deviation; V – variance; CV – coefficient of variation; Min – minimal; Max – maximal; CA – coefficient de asymmetry; Ck – coefficient of Kurtosis; FD – furrow depth (m); FC – furrow coverage (cm); FS – furrow space (m).

The depth of the furrow (Figure 2) for the day shift presented stable process according to the control chart for individual values. Because all observations were within the lower and upper control limits based on three times the standard deviation, for both charts, only natural causes acting during the process were observed.

The day shift showed 28 of the 30 points observed within the specific control limits of the unit, presenting only two points below the lower specific limit in observations 5 and 17, showing the stability of the process for planter (Figure 2a). And for distributor showed 27 of the 30 points observed within the specific control limits of the unit, presenting only three points below the lower specific limit in observations 5, 11 and 16 (Figure 2b). The night shift presenting only two points below the lower specific limit in observations 31 and 36, showing the stability of the process for distributor while for planter presenting seven points below the lower specific limit. This small variation in the data below the specific limit is due to the study area that in most places the slope was less than 1%, with the average of the area being 4.45%.

AGRARIAN
OPEN ACCESS
e-ISSN: 1984-2538

Figure 2. Control charts for the furrow depth (m) in the mechanized operation of sugarcane planting. (a) Planter. (b) Distributor. HLC: High Limit of Control. SHL: Specific High Limit. LSL: Low Specific Limit. LLC: Low Limit of Control. X: average.



The furrow coverage (Figure 3a) for the day shift the planter presented an unstable process due to observation nº 8 in the individual value chart that presented low value of furrow coverage, what was considered as an outlier. For the distributor, no out-of-control points were observed.

The night shift presented a stable process according to the individual value chart (Figure 3) for planter and distributor.

The planter in both shifts showed highest number of observations within the specific limits sought by the production unit. Values of furrow depth out of the limit parameters, what can contribute on yield reduction in the observed points because, furrow depth has a high correlation with soil moisture access, limiting the plant growth when is in shortage rates.

The furrow spacing (Figure 4) presented a stable process for the two shifts and planter or distributor according to the individual value charts, although, were observed several points above or below specific limits. This variation can be explained by the use of manual plantation management.

OPEN ACCESS
e-ISSN: 1984-2538

Figure 3. Control charts of control for the furrow coverage (m) in the mechanized operation of sugarcane planting. (a) Planter. (b) Distributor. HLC: High Limit of Control. SHL: Specific High Limit. LSL: Low Specific Limit. LLC: Low Limit of Control. X: average.

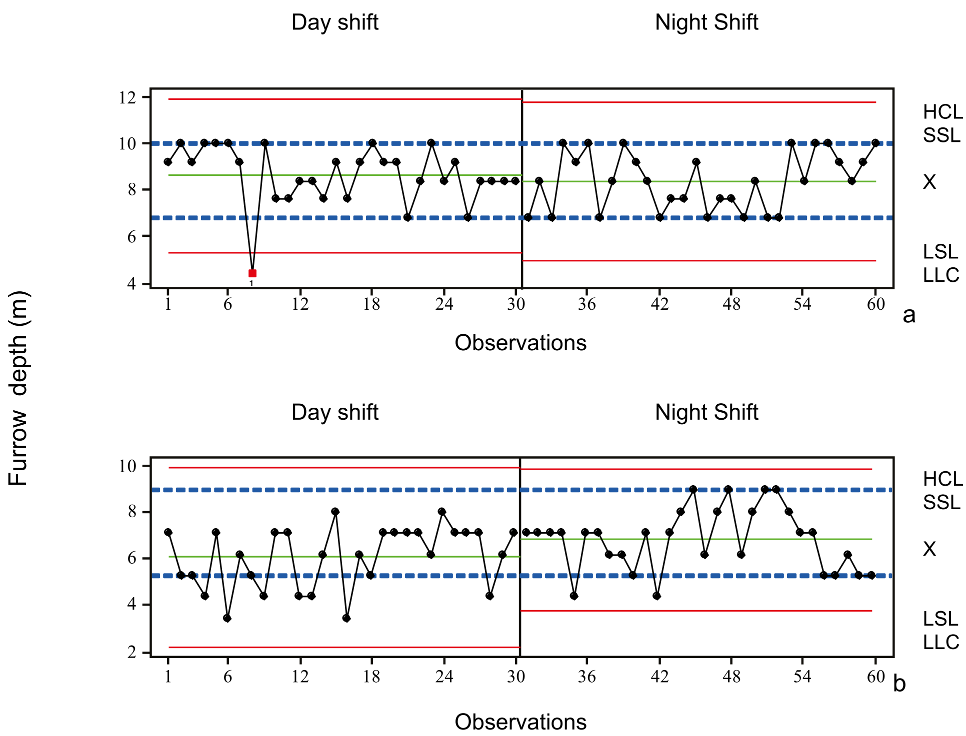
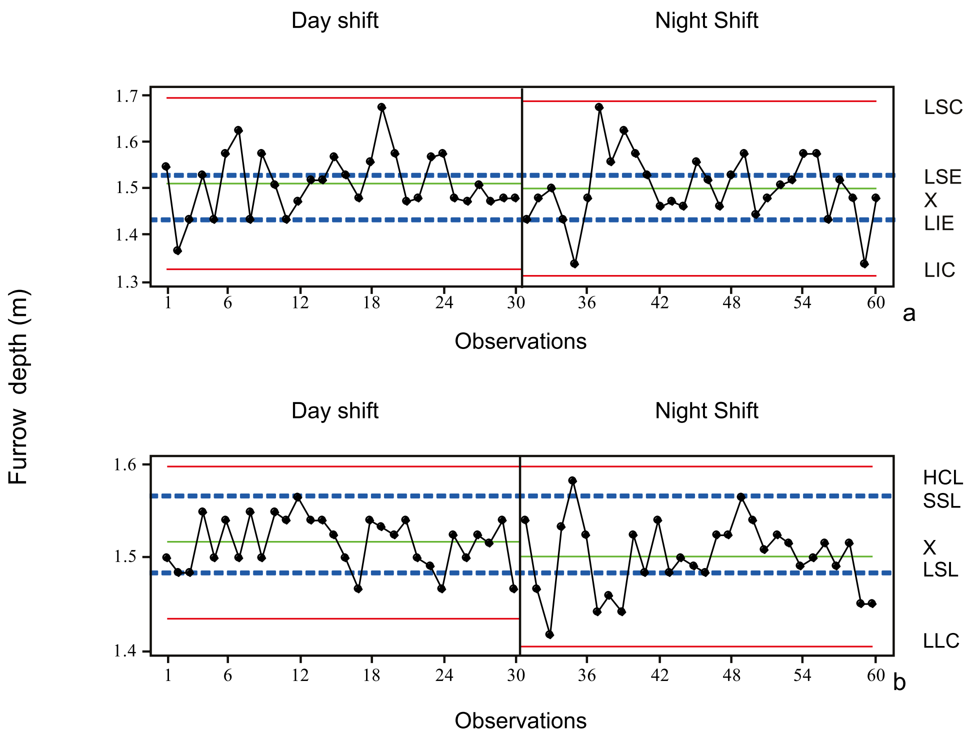


Figure 4. Charts of control for the furrow spacing (m) in the mechanized operation of sugarcane planting. (a) Planter. (b) Distributor. HLC: High limit of control. SHL: Specific high limit. LSL: low specific limit. LLC: low limit of control. X: average.



4 Discussion

The coefficient of variation (Table 2) was between low to high values depending on the variable. Raveli (2013) evaluating the mechanized sugarcane planting operation observed low values of coefficient of variation for FS and medium values for FD with values similar to those observed in this work. Was observed non-significance effect for FD, FC and FS for both sowing shifts due to the quality of the operation.

The depth of the furrow (Figure 2) all observations were within the lower and upper control limits based on three times the standard deviation, for both charts, with only natural causes being observed during the process. The presence of the points within the specific control limits for the day or night shift and planter or distributor, due to the relief of the area and the uniformity of the soil profile at the time of planting. According to Furlani and Voltarelli (2015), the ideal furrow depth for the good development of the sugarcane crop should be between 0.20 and 0.30 m values, results that areclose to those found in this study, which averaged 0.28 m.

Outlier (Figure 3) is value within the observations that is outside the normal standards, presenting a great distance from the values obtained, dues to errors such as: failure machine operability, records failure, miss-codding, data entry errors, failure on the experimental planning, or because the data came from different populations (Guedes, 1996). Furthermore, was observed an average of furrow coverage of 8.3 cm for the day shift and 7.97 cm for the night, values what are in accordance with those recommended by Coleti and Stupielo (2006) and Beauclair and Scarpari (2006) suggesting furrow coverage of 5 to 10 cm.

The variation in furrow spacing may have undesirable consequences for sugarcane cultivation, such as trampling of the sugarcane shoots in subsequent operations to planting. However, for both implements (planter and distributor) no less than 1.35 m (LSL <1.35 m) furrows spacing was obtained (Figure 4), therefore, according to Barros and Milan (2010), there is no probability of high trampling index when mechanized harvesting is performed in this.

Baio (2012) in order to perform mechanized harvesting operation, is essential to ensure the best possible quality and the lowest trampling of the sugarcane shoots, demanding to use automatic routing in the mechanized plantation of the sugarcane with the least possible miss-alignment to allow that the rows can be used at the time of harvest, ensuring better results. Moreover, in order to make the process meeting the specific limits of control of the unit, it is necessary to implement an automated system of mechanized planting to reduce errors on furrow spacing. Beauclair and Scarpari (2006) observed that mechanically harvested sugarcanes with spaces of 1.50 m have presented operational advantages, minimizing the trampling of the sugarcane rows. However, when evaluating the quality of the furrow spacing for two methods of orientation of the furrowing operation, using or not auto steering, Campos (2007), found that both methods were out of control, not meeting the limit standards of the operation.

In the control charts presented in Figures 2, 3 and 4, was observed that, except for day-planting shift with planter, the furrow coverage, the indexes of the other mechanized planting quality indicators were under statistical control, meaning that these no exceeded the upper and lower limits of control, therefore, there was only a presence of random (intrinsic) causes to the process (Voltarelli *et al.*, 2015).

Furthermore, was observed that the soil preparation system in sugarcane planting stalks is essential for better development of the crop, and the evaluation through the indicators of quality such as furrow width, furrow depth and furrow size of the clods are the most important for better understanding of crop development (Milan *et al.,* 2003).

Barros and Milan (2010), studying the quality of sugarcane plantation verified 16 critical factors in the planting process, which two of them were considered as non-predictable. These factors were the spacing between furrows and furrow depth. Such evaluations made them concluding that there are special causes that make the process unpredictable; in this case it is necessary to elaborate improvement to increase the number of points within the control limits.

The furrow depth, furrow coverage and furrow spacing parameters analyzed in work showed high planting quality for both shifts, corroborating with the results obtained by Cortez *et al.* (2016) when studying the quality of mechanized planting from the analysis of parameters of damage in pre-planting seedlings and number of shots, number of total buds, number of viable and non-viable buds, percentage of viable buds, seedling consumption and percentage of failures. Moreover, these authors observed a quality stable in planting process, but identified that greater seedling consumption is needed to avoid miss-seedling deposition and possible replanting, although, as an alternative, is necessary to intensify the trainings of operators in order to achieve the best expected results and guarantee work qualify.

Improvements in the quality of mechanized agricultural processes can be achieved by establishing an improvement plan, which includes training, monitoring and follow-up of the technical team involved in the operation cooperating with specified trainers (Arcoverde *et al.*, 2016). The identification of causes of variability and instability allows intervention and correction by increasing the quality of the operation all over time in order to increase the indexes between the limits specified by the producing unit. In mechanized planting of sugarcane, it is crucial to identify critical process factors (Barros & Milan 2010), because any decision-taken at this stage influences the whole cycle and the planting process, reflecting on the economic cycle of the crop.

5 Conclusions

The quality parameters of the mechanized planting of sugarcane are not influenced either by diurnal or nocturnal shifts, and present values considered satisfactory when performing the mechanized planting with planter or distributor.

Descriptive statistic showed us non-difference for both shifts in furrow depth, furrow spacing and furrow coverage, what was only possible through statistic control quality, enabling the visualization of presence of random causes to the process.

6 Acknowledgments

Thanks to CAPES for the master’s degree scholarship of the first author.

We have no conflict of interest to declare.

7 References

Albiero, D., Macie, A.J.S., Milan, M., Monteiro, L.A., & Mion, R.L. (2012). Avaliação da distribuição de sementes por uma semeadora de anel interno rotativo utilizando média móvel exponencial. *Revista Ciência Agronômica*, 43(1), 86-95. https://doi.org/10.1590/S1806-66902012000100011

Arcoverde, S.N., Souza, C.M.A., Cortez, J.W., Guazina, R.A., & Maciak, P.A.G. (2016). Qualidade do processo de semeadura da cultura do milho de segunda safra. Revista Engenharia na Agricultura, 24(5), 383-392. https://doi.org/10.13083/reveng.v24i5.709

Baio, F.H.R. (2012). Evaluation of an auto-guidance system operating on a sugarcane harvester. Precision Agriculture, 13(8), 141-147. https://doi.org/10.1007/s11119-011-9241-6

Barros, F.F., & Milan, M. (2010). Qualidade operacional do plantio de cana-de-açúcar.

Bragantia, 69(1), 221-229. https://doi.org/10.1590/S0006-87052010000100028

Beauclair, E.G.F., & Scarpari, M.S. (2006). Noções Filotécnicas. In: Ripoli, T.C.C., Ripoli, M.L.C. & Casagrandi, D.V. *Plantio de Cana de Açúcar: estado da arte*. Viçosa: Ceres.

Campos, C.M. (2007). *Identificação e avaliação de variáveis críticas no processo de produção da cana-de-açúcar*. Dissertação de Mestrado - Universidade de São Paulo, Piracicaba.

Chioderoli, C.A., Silva, R.P., Noronha, R.H.F., Cassia, M.T., & Santos, E.P. (2012). Perdas de grãos e distribuição de palha na colheita mecanizada de soja. *Bragantia*, 71(1), 112–121. https://doi.org/10.1590/S0006-87052012005000003

Coleti, J.T., & Stupielo J.J. (2006). *Plantio da cana-de-açúcar*. In: Segato, S.V., Pinto, A.S., Jendiroba, E. & Nóbrega, J.C. (2006). Atualização em produção de cana-de-açúcar. Piracicaba: Livroceres.

Conab - Companhia Nacional de Abastecimento. (2015). *Acompanhamento de safra brasileira: cana-de-açúcar*. Available: http://www.conab.gov.br/OlalaCMS/uploads/arquivos /16_12_27_16_30_01_boletim_cana_portugues_-3o_lev_-_16-17.pdf. Access: 20 august 2018.

Cortez, J.W., Missio, C., Barreto, A.K.B., Silva, M.D., & Reis, G.N. (2016). Quality of sugarcane mechanized planting. *Engenharia Agrícola*, 36(6), 1136–1144. https://doi.org/10.1590/1809-4430-eng.agric.v36n6p1136-1144/2016

Furlani, C.E., & Voltarelli, M.A. (2015). Plantio mecanizado de cana-de-açúcar: aspectos sobre o plantio mecanizado e resultados no campo. In: Belardo, G.C., Cassia, M.T. & Silva, R.P. *Processos agrícolas e mecanização da cultura da cana-de-açúcar.* 1 ed. Jaboticabal: SBEA.

Guedes, T.A. (1996). *Procedimentos de otimização no planejamento e controle de qualidade de produtos e processos*. Tese de Doutorado – Universidade Federal de Santa Catarina, Florianópolis.

Única. (2018). Available: http://www.sugarcane.org/ Access: 22 June 2018.

Melo, R.P., Albiero, D., Monteiro, L.A., Souza, F.H., & Silva, J.G. (2013). Qualidade na distribuição de sementes de milho em semeadoras em um solo cearense. *Revista Ciência Agronômica*, 44(1), 94-101. https://doi.org/10.1590/S1806-66902013000100012

Milan, M., Barros, J.W.D., & Gava, J.L. (2003). Planning soil tillage using quality function deployment. *Scientia Agricola*, 60(2), 217–221. http://dx.doi.org/10.1590/S0103-90162003000200003

Noronha, R.H.F., Silva, R.P., Chioderoli, C.A., Santos, E.P., & Cassia, M.T. (2011). Controle estatístico aplicado ao processo de colheita mecanizada diurna e noturna de cana-de-açúcar. *Bragantia*, 70(4), 931- 938. http://dx.doi.org/10.1590/S0006-87052011000400028

Pimentel-Gomes, F. (2009). *Curso de estatística experimental*. Piracicaba: FEALQ.

Raveli, M.B. (2013). *Controle de qualidade no plantio de cana-de-açúcar*. Dissertação de Mestrado – Universidade Estadual Paulista, Jaboticabal, 66p.

Silva, R.P., Cassia, M.T., Voltarelli, M.A., Compagnon, A.M., & Furlani, C.E.A.F. (2013). Qualidade da colheita mecanizada de feijão em dois sistemas de preparo do solo. *Revista Ciência Agronômica*, 44(1), 61-69. http://dx.doi.org/10.1590/S1806-66902013000100008

Voltarelli, M.A., Silva, R.P., Zerbato, C., Silva, V.A.F., & Cavichioli, F.A. (2014). Agronomic capability of mechanized sugarcane planting. *Australian Journal Crop Science*, 8(10), 1448-1460. https://search.informit.org/doi/10.3316/informit.752576892287644

Voltarelli, M.A., Silva, R.P., Cassia, M.A., Ortiz, D.F., & Torres, L.S. (2015). Qualidade do corte basal de cana-de-açúcar utilizando-se de três modelos de facas. *Engenharia Agrícola*, 35(3), 528–541. https://doi.org/10.1590/1809-4430-Eng.Agric.v35n3p528-541/2015

Voltarelli, M.A., Silva, R.P., Rosalen, D.L., Zerbato, C., & Cassia, M.A. (2013). Quality of performance of the operation of sugarcane mechanized planting in day and night shifts. *Australian Journal Crop Science*, 7(9), 1396-1406. http://hdl.handle.net/11449/76304