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SUGARCANE BASE CUTTING QUALITY USING RECTANGULAR AND CIRCULAR BLADES

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KEYWORDS

cutting height, control charts, mechanized harvesting, damages and disturbances, *Saccharum* spp.

ABSTRACT

Sugarcane mechanized harvesting can lead to serious risks to the longevity of plantations when improperly operated, and may cause damages and disturbances in the remaining ratoons in the field. In this sense, this study aimed to evaluate the damage and disturbance to the sugarcane ratoons by the base cutting quality of two-blade models through statistical process control. The experiment was carried out during the 2015/16 growing season in an agricultural area of the Moreno Mill, located in Cravinhos, São Paulo, Brazil. The sugarcane harvester models A8800 (Machine 1) and BE1035 (Machine 2). The sugarcane variety cultivated in both treatments was SP80-1816. Thirty points were sampled per harvester, with 10-minute intervals between them. Equations were used to calculate the indices, which were then evaluated through descriptive analysis and statistical process control. Machine 2 presented process instability for the index of damages, with lower data variability. On the other hand, Machine 1 presented instability during the process due to the quality indicator and index of disturbance, but with a lower operation variability.

INTRODUCTION

Sugarcane is one of the most important crops for Brazilian agribusiness, with an area of about 8,973.2 million hectares destined to sugar and alcohol production, making Brazil the world's largest producer. Recently, its residual products have been used for the generation of renewable electrical energy (bioelectricity) from the burning of bagasse and straw. However, the sugarcane production in Brazil decreased by 3.9% in the 2015/16 growing season compared to 2014/15 (Conab, 2016).

The possible reason for this decrease in sugarcane production is related to damages and disturbances in the ratoons caused by harvesters, reducing sprouting in the next growing seasons and providing the attack of diseases and pests, which reflect in the yield loss. Another situation is the intense traffic of harvesters and loading systems (tractor/wagon) in areas that have not been properly systematized, which cause trampling of the sugarcane rows and result in losses of vigor, failures, and lower development in plant population in subsequent growing seasons due to damages to ratoons (Manhães et al., 2014).

The different types of components of the basal cutting mechanism, composed of rotating discs with multiple cutting blades, have a high influence and importance in the sugarcane ratoon damage, which can cause higher stalk tearing, destroying or mechanically removing the ratoons (Cassia et al., 2014).

In this sense, some authors have used statistical process control tools to monitor the operations and mechanized harvesting of sugarcane, allowing managing and pointing out undesirable causes, as well as creating an efficient action plan to raise the quality of these processes (Silva et al., 2014).

Statistical process control (SPC) aims to detect quick changes in parameters of certain processes to identify special (out of control points) or non-random causes resulting from the process variability (CASSIA et al., 2014; Chioderoli et al., 2012; Ormond et al., 2015; Zerbato et al., 2013). Thus, this study aimed to evaluate the quality of the sugarcane base cutting process through the statistical process control using circular and rectangular blades.

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MATERIAL AND METHODS

The experiment was carried out in areas of the Moreno Mill, located in Cravinhos, SP, Brazil, close to the geographic coordinates 21°24′09.11″ S and 47°49′10.41″ W, with an average altitude of 604 m. The regional climate is classified as Cwa, according to the Köppen classification. The soil of the experimental area is classified as an Oxisol with smooth wavy relief (Embrapa, 1999).

The sugarcane variety grown in both treatments was SP80-1816, which was in the 3rd ratoon cut, with productivity of 75.9 t ha^{-1}. This variety stands out for its ratoon sprouting, rapid vegetative growth, and erect growth habit, being an excellent option for mechanized harvesting.

Two harvesters were used in the experiment. Machine 1 consisted of a 2014 Case IH A8800 with a 263-kW (358-hp) Cummis Case IH C9 engine, hydrostatic transmission, and equipped with a track wheelset with a nominal width of 1.88 m, working at a speed of 5.5 km h^{-1}. Its cutting mechanism had two rotating discs with six racket-type circular blades on each disc, totaling 12 blades in the set. The rotation of the primary extractor throughout the harvest was 800 rpm. Machine 2 consisted of a 2016 Valtra BE 1035E with a 257-kW (350-hp) AGCO Power engine and equipped with a track wheelset, working at a speed of 4.0 km h^{-1}. Its cutting mechanism had two rotating discs with four conventional blades on each disc, totaling eight blades in the set. The rotation of the primary extractor was 1300 rpm in the morning and 1000 rpm in the afternoon.

The experimental design followed the SPC premises, in which monitoring is performed over time. Therefore, the sample points were collected at 10-minute intervals from one point to another, totaling 30 samples for each harvester.

The cutting height and indices of damage and disturbance to the sugarcane ratoons were determined within a 0.25-m^2 (0.50 × 0.50 m) square metal frame by evaluating an average of eight stalks in each sample. The data was collected by the same person throughout all hours worked to guarantee high control of the experimental conditions.

The damages caused to the sugarcane ratoons were classified into stalks with no damage (ND = 0 to 0.33), partial damage (PD = 0.34 to 0.66), and fragmented stalks (FR = 0.67 to 1.00). This classification was carried out through the visual evaluation of all stalks present in each ratoon.

The index of damage caused to the sugarcane ratoon was determined based on this classification, according to the methodology proposed by Toledo et al. (2013). This index represents, in a single value, the classification attributed to the sugarcane ratoon, according to [eq. (1)]:

$$I_{Dam} = \frac{NDw \times NDn + PDw \times PDn + FRw \times FRn}{n} \quad (1)$$

in which,

NDw is the weight attributed to stalks with no damage;

NDn is the number of stalks with no damage;

PDw is the weight attributed to stalks with partial damage;

PDn is the number of stalks with partial damage;

FRw is the weight attributed to stalks with fragmented damage;

FRn is the number of stalks with fragmented damage, and

n is the total number of stalks in the sugarcane ratoon.

The disturbances to ratoons were measured through the application of manual force, evaluating the strength of stalks in each ratoon, being classified as strong, medium, or weak (Toledo et al., 2013). The index of disturbance to the sugarcane ratoon was determined based on this analysis, according to [eq. (2)].

$$I_{Dist} = \frac{SDw \times SDn + MDw \times MDn + WDw \times WDn}{n} \quad (2)$$

Where:

I_{Dist} is the index of disturbance to the sugarcane ratoon;

SDw is weight attributed to stalks with a strong disturbance (1.00);

SDn is the number of stalks with a strong disturbance;

MDw is the weight attributed to stalks with a medium disturbance (0.33);

MDn is the number of stalks with a medium disturbance;

WDw is the weight attributed to stalks with a weak disturbance (0.00);

WDn is the number of stalks with a weak disturbance, and

n is the total number of stalks in the ratoon.

The interpretation of eqs (1) and (2) is based on the following logic: the closer to 1 the value is (fragmented damage/strong disturbance), the higher damage and disturbance caused in the ratoon (higher number of fragmented/disturbed stalks compared to other classifications). On the other hand, values closer to 0 means that the stalks had lower damage and/or lower disturbance to the sugarcane ratoon. Values equal to 0 means that the harvesting process caused no damages to the ratoon (no damage/weak disturbance).

The cutting height was measured using a graduated ruler from the ground level to the point where the blade cut the stalk. The height was considered zero when the cut was performed below the soil surface. The square metal frame used to analyze the damages, disturbances, and cutting height in the sugarcane ratoon was placed on the harvest row after the machines have passed and allowed the average evaluation of eight ratoons per point.

The data were analyzed using descriptive statistics, aiming to verify the response of the data set in the harvesting process before proceeding with the construction of the control charts. Measures of central tendency (mean), dispersion (standard deviation and coefficient of variation), and skewness and kurtosis were calculated. The Ryan-Joiner test was used to verify the normality of the data.

The base cutting quality was analyzed for each harvester using the statistical process control through individual and moving range control charts, allowing verifying the uniformity of the process (Compagnon et al., 2012). Voltarelli et al. (2013) pointed out that these control charts relate aspects of the studied subject with the number of samples collected over time. This control chart model has two graphs: the upper chart, corresponding to the individual values sampled at each point; and the lower chart, representing the moving range calculated between the differences of two successive considerations. The limits of the control charts and center lines were performed using eqs (3) and (4):

$$\text{UCL} = \bar{X} + 3\sigma \quad (3)$$

$$LCL = \bar{X} - 3\sigma \quad (4)$$

Where:

UCL is the upper control limit;

LCL is the lower control limit;

$\bar{X}$ is the center line, and

σ is the standard derivation.

No point out of control limits on the control chart means no-fault observation in the process, that is, there are no special causes of variation and, consequently, the process is stable. One point out of control means that there is a non-random variation in the results. These variations can be due to a special cause, which makes the process unstable (out of control). The process needs further investigation under these situations, considering the 6 M's factors (method, machine, material, manpower, mother nature, and measurement) to identify the points responsible for this variation and eliminate them.

RESULTS AND DISCUSSION

The indices of damage and disturbance to the sugarcane ratoon showed a normal probability distribution according to the Ryan-Joiner test, which means that the values collected in the field are around the estimated line (Table 1). According to Noiman et al. (2014), the higher the number of collected samples, the easier the data reach the normality due to the central limit theorem. Thus, the data under normality are subjected to monitoring, analysis, and interpretations for an assertive decision during the mechanized sugarcane harvesting.

TABLE 1. Descriptive statistics for quality indicators of the base cutting in the mechanized sugarcane harvesting.

Quality indicator	Machine 1 (circular blade)						
	$\bar{X}$	σ	CV	Cs	Ck	RJ	p-value
CH	89.50	63.60	71.10	0.68	−0.93	0.981	<0.01^A
I_{Dam}	0.32	0.17	55.38	0.48	−0.37	0.996	>0.10^N
I_{Dist}	0.26	0.16	62.63	0.19	−0.67	0.944	>0.10^N
	Machine 2 (rectangular blade)						
AC	114.00	89.2	78.24	0.76	−0.96	0.915	<0.01^A
ID	0.44	0.16	56.79	0.59	−0.04	0.979	>0.10^N
IA	0.31	0.17	35.59	0.03	−0.74	0.922	>0.10^N

CH – cutting height; I_{Dam} – index of damage index; I_{Dist} –index of disturbance; $\bar{X}$ (mm) – mean; σ – standard deviation; CV – coefficient of variation (%); Cs – coefficient of skewness; Ck – Coefficient of kurtosis; RJ – Ryan-Joiner normality test; p-value (>0.01) – N normal probability distribution; A – Non-normal probability distribution.

The quality indicator cutting height showed a non-normal distribution according to the normality test, which could be explained by the high values of the coefficients of skewness and kurtosis (Table 1). The coefficients of kurtosis and skewness had values above the average sample. It means that the positive coefficient of skewness indicated a more elongated curve to the right, in which the average value exceeds the sample median, while the negative coefficient of kurtosis indicates a more tapered curve (leptokurtic), leading to a non-normal distribution for the cutting height.

The cutting height during the mechanized sugarcane harvesting showed instability during the process for both machines. This instability in the process is evidenced by points above and below the control limits in individual and moving range control charts (Figures 1a and 1b). Points above the control limits (highest values) for the quality indicator cutting height are associated with an increased working speed of the harvester (machine/manpower factor), the inefficiency of the automatic cutting height control (machine factor), the unevenness of the soil micro-relief (mother nature/machine/manpower factor), and the operator carelessness when driving the base cutting mechanism (manpower factor), with external factors acting throughout the operation.

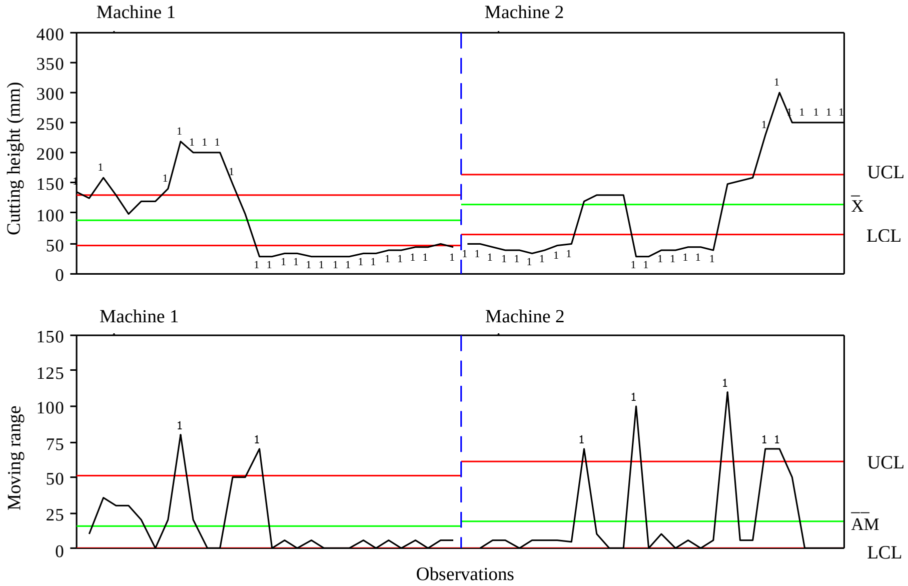

FIGURE 1. Individual (a) and moving range (b) control charts for the cutting height in the mechanized sugarcane harvesting. Machine 1 – circular blades; Machine 2 – rectangular blades.

The lower variability of the operation was observed in the treatment harvested by Machine 1, showing the best quality of the operation (Figures 1a and 1b). The control charts showed that values above the average could be detrimental to the mechanized harvesting quality, as the stalk pieces left in the field constitute stump losses, which represent the highest amount of sucrose in the sugarcane. On the other hand, the lowest cutting height values can be positively related to the mechanized harvesting, regardless of being below the lower control limit.

Reis et al. (2015) evaluated the quality of the base sugarcane cutting mechanism as a function of soil management and reported an increase in the variability of the cutting height during the harvesting process as soil mobilization increased due changes in the micro-relief.

The quality indicator index of damage to the sugarcane ratoon showed process stability for Machine 1. It means that all sample points are between the control limits in both control charts (Figures 2a and 2b).

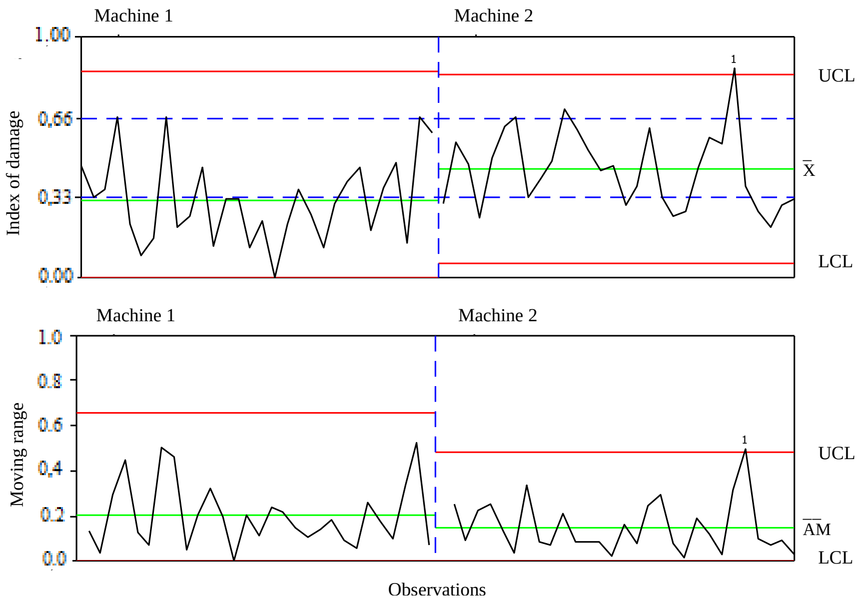

FIGURE 2. Individual (a) and moving range (b) control charts for the index of damage to the ratoons in the mechanized sugarcane harvesting. Machine 1 – circular blades; Machine 2 – rectangular blades.

In contrast, the process carried out with Machine 2 showed instability, as at least one point was above the UCL for individual and moving range charts. This situation may be related to a peak in the harvester speed, affecting the quality of the base cutting when the blade touches the sugarcane stalk, causing its shear. Toledo et al. (2013) and Voltarelli et al. (2017) found similar results. These authors observed that the highest harvester speed could negatively affect the base cutting quality. In addition, the lowest variability was observed for Machine 2, regardless of the process instability. This situation occurred because the sample points are close to the average value (Figure 2b).

Machine 1 provided damages classified into no damages (50%) and partial damages (50%) to the sugarcane ratoon, with no fragmented damages, reflecting the quality of mechanized sugarcane harvesting (Figure 2a).

The quality indicator index of disturbance to the ratoons showed instability during the process for Machine 1, with a point above the UCL in the moving range chart (Figure 3b). On the other hand, Machine 2 presented a stable process throughout the mechanized sugarcane harvesting, with only random causes acting during the operation (Figure 3a).

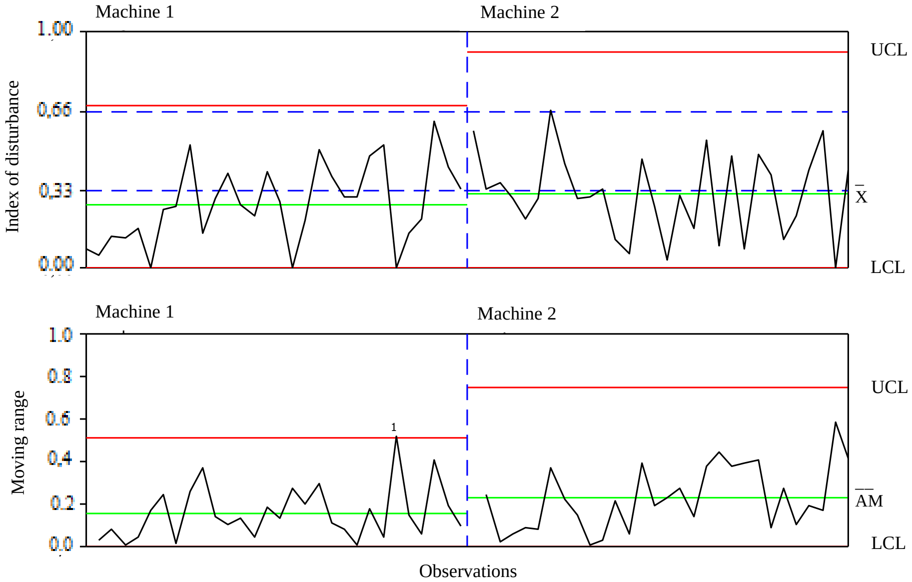

FIGURE 3. Individual (a) and moving range (b) control charts for the index of disturbance to the ratoons in the mechanized sugarcane harvesting. Machine 1 – circular blades; Machine 2 – rectangular blades.

The lowest variability in the operation was observed for Machine 1, as shown by the smallest amplitude between the lower and upper control limits. Moreover, 67 and 33% of the index of damage was within the classification no damage and partial damage, respectively. In contrast, the percentage of classification with no damage and partial damage was 53 and 47% for Machine 2, respectively (Figures 3a and 3b).

The process was unstable for Machine 1 despite its lowest variability. It is associated with the variation of values between the samples collected throughout the harvest, reflecting the high variability of the data set between ratoon damage classes. Similarly, Voltarelli et al. (2017) studied the indices of disturbance and damage in sugarcane ratoons using different blade models and angles of attack and reported instability of the quality indicator index of disturbance of ratoons despite its less variability in the data set.

CONCLUSIONS

Machine 2 showed instability during the process relative to the index of damage even using the conventional (rectangular) blade. Also, lower variability in the data was observed regardless of the process instability.

The quality indicator index of disturbance to the sugarcane ratoon showed instability during the process for Machine 1 (racket-type circular blades). However, the operation showed lower variability.

The cutting height of both machines showed process instability, with higher data variability for Machine 2 (rectangular blades).

REFERENCES

Cassia MT, Silva RP, Paixão CSS, Bertonha RS, Cavichioli FA (2014) Desgaste das facas do corte basal na qualidade da colheita mecanizada de cana-de-açúcar. Ciência Rural 44(6):987-993.

Chioderoli CA, Silva RP, Noronha RHF, Cassia MT, Santos EP (2012) Perdas de grãos e distribuição de palha na colheita mecanizada de soja. Bragantia 71(1):112-121.

Compagnon AM, Silva RP, Cassia MT, Graat D, Voltarelli MA (2012) Comparação entre métodos de perdas na colheita mecanizada de soja. Scientia Agropecuária 3(3):215-223.

CONAB – Companhia Nacional de Abastecimento. Available: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/16_04_18_14_27_15_boletim_cana_portugues_-_1o_lev_-_16.pdf>. Acessed Nov 29, 2016.

EMBRAPA. Empresa Brasileira de Pesquisa Agrícola (1999) Sistema brasileiro de classificação de solos. EMBRAPA/CNPS, 412p.

Manhães CMC, Garcia RF, Correa Junior D, Francelino FMA, Francelino HO, Santos CMG (2014) Evaluation of visible losses and damage to the ratooncane in the mechanized harvesting of sugarcane for diferente displacement speeds. American Journal of Plant Sciences 5(20):2956-2964.

Ormond ATS, Voltarelli MA, Paixão CSS, Gírio LA.S, Zerbato C, Silva RP (2015) Características agronômicas da soja em semeadura convencional e cruzada. Revista Agro@ambiente 9(4):414-422.

Reis GN, Voltarelli MA, Silva RP, Toledo A, Lopes A (2015) Quality harvesting in the basement cut of sugarcane soil management systems. Comunicata Scientiae 6(2):143-153.

Silva RP, Voltarelli MA, Cassia MT, Vidal DO, Cavichioli FA (2014) Qualidade das operações de preparo reduzido do solo e transplantio mecanizado de mudas de café. Coffee Science 9(19):51-60.

Toledo A, Silva RP, Furlani CEA (2013) Quality of cut and basecutter blade configuration for the mechanized harvest of green sugarcane. Scientia Agricola 70: 384-389.

Voltarelli MA, Silva RP, Rosalen DL, Zerbato C, Cassia MT (2013) Quality of performance of the operation of sugarcane mechanized planting in day and night shifts. Australian Journal of Crop Science 7(9):1396.

Voltarelli MA, Silva RP, Cassia MT, Daloia JGM, Paixão CSS (2017) Qualidade do corte basal de cana-de-açúcar efetuado por facas de diferentes angulações e revestimentos. Revista Ciência Agronômica 48(3):438.

Zerbato C, Furlani CEA, Bertonha RS, Cavichioli FA, Raveli MB (2013) Análise de componentes principais na operação da semeadura de feijão em função do preparo do solo. Energia na Agricultura 28(2):74-78.