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SUGARCANE MECHANIZED HARVEST QUALITY IN YIELD RANGES

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ABSTRACT: Based on information about the area in which sugarcane will be cultivated, yield ranges can be determined. The yield and cultivar adopted directly interfere in the harvest. Mechanized harvesting has advantages in the sugarcane production, but losses occur in this process. In this sense, the objective was to evaluate the mechanized harvesting quality of two sugarcane cultivars (CTC4 and SP86-0155) in three yield ranges (50 to 70, 71 to 90 and 91 to 120 t ha^{-1}). The experiment was carried out in six areas in the region of the municipality of Jaboticabal-SP. In each area, yield and visible losses were determined at twelve points. The data were submitted to descriptive analysis and as a tool to analyze the harvest quality, the statistical process control (SPC) was used. The results indicate 54% higher losses in high yield ranges, and lower process quality. The cultivar SP86-0155 presented 11% less loss at harvest regarding to the cultivar CTC4, a fact that is related to the cultivars morphological characteristics.

Keywords: *Saccharum officinarum* L., statistical process control, visible losses.

QUALIDADE DA COLHEITA MECANIZADA DA CANA-DE-AÇÚCAR EM FAIXAS DE PRODUTIVIDADE

RESUMO: Baseado na informação acerca da área cultivada com cana-de-açúcar, faixas de produtividade podem ser distinguidas. A produtividade e a cultivar utilizadas interferem diretamente na colheita. A colheita mecanizada apresenta vantagens no sistema de produção de cana-de-açúcar, porém podem ocorrer perdas nesse processo. Nesse sentido, o objetivo foi avaliar a qualidade da colheita mecanizada de duas cultivares de cana-de-açúcar (CTC4 e SP86-0155) em três faixas de produtividade (50 a 70, 71 a 90 e 91 a 120 t ha^{-1}). O experimento foi realizado em seis áreas na região do município de Jaboticabal-SP. Em cada área foram determinados a produtividade e as perdas visíveis em doze pontos. Os dados foram submetidos à análise descritiva e como ferramenta para analisar a qualidade da colheita, o controle estatístico do processo (CEP) foi utilizado. Os resultados indicaram incremento de 54% em faixas de produtividades mais altas e menor qualidade do processo de colheita. A cultivar SP86-0155 apresentou 11% menos perdas na colheita comparada à cultivar CTC4, fato que pode estar relacionado às características morfológicas das cultivares.

Palavras-chave: controle estatístico do processo, perdas visíveis, *Saccharum officinarum* L.

1 INTRODUCTION

Brazil has highlighted in the sugar-alcohol sector for being the world sugarcane largest producer, with a yield of approximately 69 thousand kg ha^{-1} in the 2021/22 harvest (CANA-DE-AÇÚCAR, 2022). The country also stands out in the production of sugar and ethanol (SANTORO; SOLER; CHERRI, 2017). The main mills are concentrated in the Southeast region, mainly in the São Paulo state, which represents 51% of the total sugarcane production (CANA-DE-AÇÚCAR, 2022).

Due to the crop’s importance, new cultivars are developed to be more resistant to diseases and obtain higher yields (SCHMITZ;

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KENNEDY; ZHANG, 2020). The response of sugarcane cultivars is dependent on the interaction with the crop environment (BARBOSA *et al.*, 2021). The "Sugarcane Production Environments" system aims to distinguish the yield potential of environments in Brazil. The environments vary with the chemical, physical and hydric soil attributes and climatic conditions (VITTI; PRADO, 2012). From the environmental analysis, the soils are classified for sugarcane production and with this information, it is also possible to determine yield ranges for each of these environments (SILVA; ALVES; FREITAS, 2015). The allocation of sugarcane production environments allows for more assertive management of cultivars, soil tillage, planting, crop traits, and harvesting (BENEDINI; BERTOLANI, 2008).

Harvesting is one of the most important stages of the field processes, as it involves high operating costs and directly influences the material quality (MARTINS *et al.*, 2021). In Brazil, since 2017, sugarcane harvesting should only take place mechanized, due to socio-environmental issues (CARDOSO *et al.*, 2018; SANTORO; SOLER; CHERRI, 2017; SILVA *et al.*, 2021). Mechanized harvesting promotes benefits to the cropping system, such as soil erosion protection and nutrient cycling. However, there may be losses in the raw material quality, increased field losses, damage to the ratoon, and reduced cane field longevity (SILVA *et al.*, 2021).

Mechanized harvesting allowed the production of cultivars with higher sucrose content, despite having a greater tendency to lodging. Thus, there is a direct relationship between the technology used in the harvesting and the sugarcane cultivar (SCHMITZ; KENNEDY; ZHANG, 2020).

Currently, the objective is to extract the maximum yield potential in crop areas, aiming to minimize quantitative and qualitative harvesting losses. Factors can influence the number of visible losses during mechanized harvestings, such as yield, cultivar characteristics, terrain slope, work speed, and harvester configuration (SANTOS *et al.*, 2019). In this sense, the study aims to evaluate the sugarcane mechanized harvesting quality of in two cultivars and three yield ranges.

2 MATERIAL E METHODS

The experiment was carried out in six locations near the municipality of Jaboticabal, São Paulo (Table 1).

Table 1. Areas where the experiment was conducted

Cultivar	Location		Sugarcane age	Yield (t ha^{-1})
CTC4	Fazenda Bela Vista	21°19'S; 48°27'W	3° cut	91 – 120
	Sítio Areias	21°19'S; 48°27'W	8° cut	71 – 90
	Sítio Bela Vista	21°15'S; 48°21'W	5° cut	50 – 70
SP86-0155	Três Irmãos	21°16'S; 48°26'W	2º cut	91 – 120
	Fazenda Areias	21°18'S; 48°26'W	4º cut	71 – 90
	Nossa Senhora de Lourdes	21°09'S; 48°25'W	4º cut	50 – 70

Fonte: Author (2021)

The treatments were two sugarcane cultivars, C1 (CTC4) and C2 (SP86-0155); and three yield ranges, F1 (50 to 70 t ha^{-1}), F2 (71 to 90 t ha^{-1}), and F3 (91 to 120 t ha^{-1}). In each treatment, twelve points were collected, following the Statistical Process Control (SPC) premises.

The cultivar CTC4 is characterized by its vigorous development, easy dehusking, good tillering, without tipping over, and adapted to mechanized harvesting, with the potential for five cuts and an average yield of 109 t ha^{-1}, reaching 129 kg t^{-1} of cane in total recoverable sugar (CENTRO DE TECNOLOGIA CANAVIEIRA, 2021). The cultivar SP86-0155 has a high yield, and good tillering but does not tolerate trampling, as it considerably reduces its regrowth capacity (GOLINSKI, 2009). Both cultivars have a medium to late cycle. Sugarcane was planted in all areas in rows spaced at 1.5 m.

The yield ranges were divided based on low, medium, and high yield classification (VITTI; PRADO, 2012), based on the evaluation of the average yield observed in the region of Jaboticabal – SP.

Harvest was carried out between September and October 2019 with the aid of a single-row CH 570 Johnn Deere harvester. The speed for the experiment was from 5.5 to 6.5 km h^{-1}, according to the terrain conditions and the standard speed adopted by the mills in the region.

The losses in the sugarcane mechanized harvesting were determined with the aid of a square frame with dimensions of 3 x 3.33 m, corresponding to a total area of 9.99 m² at each point, according to the methodology of the Sugarcane Technology Center, cited by (BENEDINI; BROD; PERTICARRARI, 2008). At each point, the straw and leaf expelled by the harvester were cleaned to visualize only the sugarcane left on the ground. All material was stored in plastic bags and weighed on a digital scale.

Descriptive analysis (mean, standard deviation, coefficient of variation, minimum value, maximum value, and range) was performed. To verify the data normality, the Anderson-Darling test was performed. The mechanized sugarcane harvesting quality was evaluated using the SPC using individual and moving averages control charts using Minitab 16.

3 RESULTS AND DISCUSSION

The treatments were normally distributed, except for C2F3 (Table 2). Data with no normal distribution can be studied using control charts, but false alarms can occur (SAMOHYL, 2009).

Table 2. Descriptive analysis and normality test for mechanized harvesting losses of two sugarcane cultivars in three yield ranges

	$\bar{X}$	σ	CV	Mn	Mx	Rg	AD
C1F1	1.16	0.39	33.20	0.62	1.70	1.08	0.59^{N}
C1F2	1.45	0.33	22.72	0.86	1.84	0.98	0.41^{N}
C1F3	2.42	0.68	28.09	1.58	3.59	2.01	0.34^{N}
C2F1	1.11	0.33	29.84	0.79	1.78	0.99	0.72^{N}
C2F2	1.55	0.57	37.00	0.88	2.85	1.97	0.46^{N}
C2F3	1.82	0.65	35.71	1.28	3.10	1.82	1.32^{A}

C1 – CTC4; C2 – SP86-0155; F1 – 50 a 70 t ha^{-1}; F2 – 71 a 90 t ha^{-1}; F3 – 91 a 120 t ha^{-1}; $\bar{X}$ – mean; σ – standard deviation; CV – coefficient of variation; Mx – maximum value; Mn – minimum value; Rg – range; AD –Anderson-Darling test; N – normal distribution data; A – no normal distribution data.
Fonte: Author (2021)

The variation coefficient presented high values (PIMENTEL-GOMES, 2009) (Table 2). The losses varied on average from 1.10 to 2.45 t ha^{-1}. The high and very high values of coefficient of variation are considered common in agricultural experiments, such as mechanized harvesting, which is subject to the interference of factors such as climate, soil, and relief.

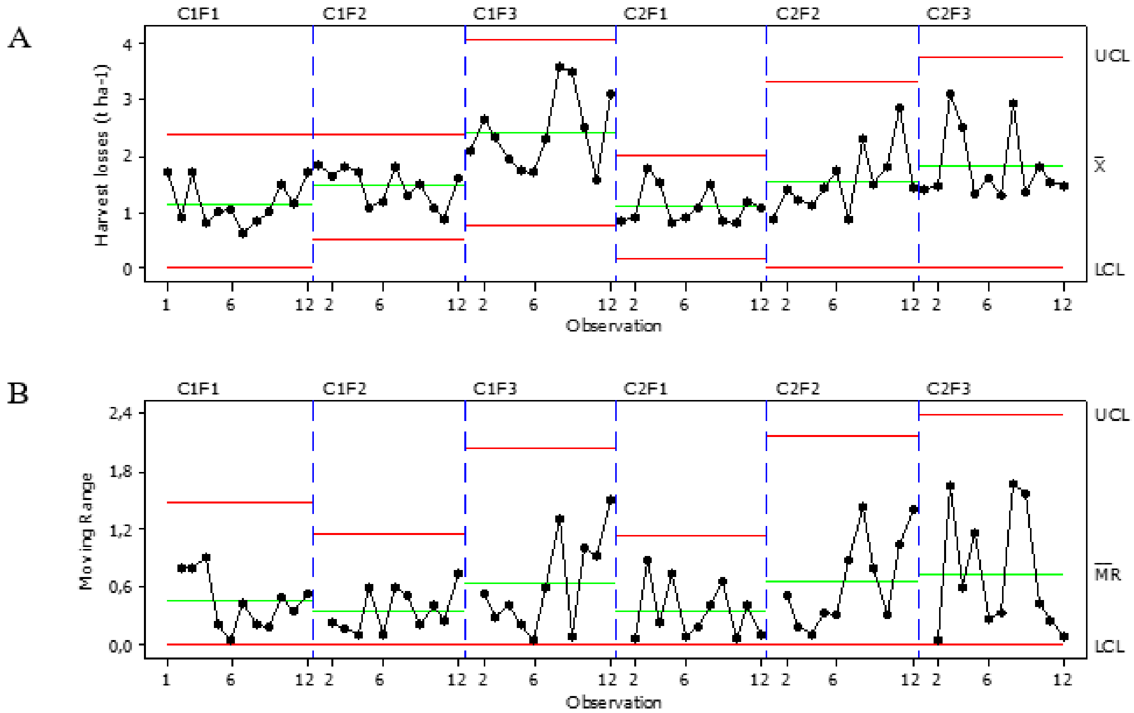
The highest data range was found in the C1F3 treatment, 51% higher than the other treatments (Table 2). The treatments presented losses within the acceptable limit (NEVES, 2006), with the upper limit in C1F3 reaching 4 t ha^{-1}, this is due to the greater amplitude in this treatment (Table 2).

The higher the yield range assigned to the sugarcane area, the greater the difficulty in obtaining a process with less variation in losses (Figure 1). Losses tend to be higher in sugarcane fields with high yields (SANTOS *et al.*, 2019).

Sugarcane fields with low yield have a more upright architecture, causing minimal contact with the harvester's row dividers. In this way, the sugarcane goes directly to the tumbler roller and continues to the base cut. By entering a smaller volume in the base cut, higher quality work is performed, providing lower rates of loss and contamination of the raw material (VOLTARELLI *et al.*, 2014).

Harvest losses were not affected by yield ranges. There were no points outside the control limits for the studied treatments (Figure 1 - A). Differences regarding process variability are observed (Figure 1).

Figure 1. Individual control chart (A) and moving range (B) for mechanized harvesting losses of sugarcane



C1 – ‘CTC4’; C2 – ‘SP86-0155’; F1 – 50 a 70 t ha^{-1}; F2 – 71 a 90 t ha^{-1}; F3 – 91 a 120 t ha^{-1}; UCL – upper control limit; LCL – lower control limit; $\overline{X}$ – mean.
Fonte: Author (2021)

The F3 shows higher process variability, which could be observed in the difference between the upper and lower control limit (Figure 1 – A). Likewise, the highest harvest losses on average (2.1 t ha^{-1}) were also observed in the F3, on average 54% higher than F1 (1.1 t ha^{-1}) (Figure 1 – A). Acceptable losses for sugarcane mechanized harvesting range from 3 to 4 t ha^{-1} (NEVES, 2006). Although within the acceptable range, it should be noted that the lower the harvest loss, the better the use of the area. Sugarcane field with high yield is neither erect nor uniform in the planting line, due to the high volume of stalks. In this way, the large volume of material causes greater pressure on the base cut and exceeds the resistance that the sugarcane harvester can withstand increasing losses.

The higher variability in C2F3 may be linked to the fact that the losses in this treatment are close to the average value with points outliers from the other observations, such as points three and eight. In the mentioned points, the machine may have overcrowding from the base cut to the conveyor rollers. This overcrowding may have been caused by a higher feed rate with a higher number of stalks at some points in the planting line.

Sugarcane mechanized harvesting involves cutting, loading, and transporting (PAIXÃO *et al.*, 2020). The base cut, when the sugarcane will be cut, is one of the main problems when studying harvest losses (VOLTARELLI *et al.*, 2017). If the stalks are more resistant, the base cut needs more pressure to process the volume to be cut (SALVI; MATOS; MILAN, 2007).

The C2F3 treatment shows higher variability, this could be observed in the moving range chart that represents the variability within the process (Figure 1 – B). Points 3, 4, and 5 presented higher losses than the other observation points.

The cultivar SP86-0155 (C2) presented 11% fewer harvest losses regarding to the cultivar CTC4 (C1). The lower percentage of loss observed in C2 is mainly due to the lower loss in treatment C2F3. Treatments C1F1 (1.17 t ha^{-1}) and C2F1 (1.11 t ha^{-1}) have lower harvest losses because they have a smaller material volume in harvest (Figure 1 - A).

'CTC4' has fine stalks, high tillering, high yield, low fiber content compared to 'SP86-0155', and great adaptability to mechanized planting and harvesting (CUNHA; PASQUALETTO, 2020). As it is a mechanized harvest, greater visible losses are expected for 'CTC4' due to its resistance to the harvester, especially in the area of the first cut with a high yield.

Still, the lower percentage of loss observed in C2 indicates that the cultivar SP86-0155 has lower harvest losses in areas with higher yields. Based on this result, it can be inferred that this cultivar or others with similar characteristics can be exploited in higher yield ranges without damage to its final yield.

The quality of the harvesting operation depends on labor qualified, sugarcane cultivars, among others (ARIYAWANSHA *et al.*, 2020). Upright cultivars with low fiber content are indicated for mechanized harvesting (SILVA; ALVES; FREITAS, 2015), a fact that differs from the objective in the final sugarcane processing, in which cultivars with higher fiber content are used desired (ARIYAWANSHA *et al.*, 2020).

4 CONCLUSIONS

- Harvest losses were not affected by the yield ranges and cultivars evaluated, there were no points outside the control limits in any treatment, that is, there is quality in the processes.
- The yield range from 91 to 120 t ha^{-1} presented 54% more raw material loss than the lowest yield range.
- Cultivar SP86-0155 showed 11% less loss at harvest than cultivar CTC4.

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