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COSTS OF SOIL PREPARATION AND SUGARCANE PLANTING SYSTEMS: DIFFERENCES BETWEEN INDEPENDENT SUPPLIERS AND SUGAR MILLS

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Abstract: Brazil is a reference in sugarcane production, especially the state of São Paulo, which is responsible for the largest volume of sugarcane production in the country. However, for sugarcane mills and suppliers to maintain this activity, there is a need to improve productivity per hectare and reduce production costs. Thus, the objective of this work is to analyze the costs of the combinations of soil preparation and planting types between sugarcane mills and suppliers. It is characterized as a quantitative study with a descriptive approach, carried out from primary data (survey of the average costs of research related to soil preparation and sugarcane planting) and secondary (cutting, loading, and transport cost and costs with cultural practices). The sample for this research comprised 31 mills and 42 sugarcane suppliers in the state of São Paulo, whose data were obtained through a survey provided data for the 2019/2020. The analysis was based on verifying the existence of a significant difference between the costs of soil preparation and planting evidenced by means of cumulative frequencies using Monte Carlo (MC) method. The results showed that, considering all possible combinations between tillage and planting systems, the lowest cost per ton was attained by suppliers with conventional tillage (CT) together with mechanized planting (MP) with variable rate for fertilizer application and also by using conventional tillage associated with planting pre-sprouted seedlings with fixed rate.

Keywords: sugarcane mills; sugarcane suppliers; Monte Carlo method; flat rate; variable rate

1 INTRODUCTION

Sugarcane has been one of the most important Brazilian agricultural products since colonial times (AMORIM *et al.,* 2019). Sugarcane-based sugar was responsible for the first great agricultural and industrial wealth accumulation in Brazil and, for a long time, was the basis of Brazilian economy.

Currently, the sugarcane agroindustry has expanded its dimensions in the country, increasing its domain over its territory. The extension of area planted with this crop almost doubled in the country, between 2003 and 2016, incorporating about 49 million new hectares National Supply Company (CONAB, 2020). According to the Sugarcane Industry

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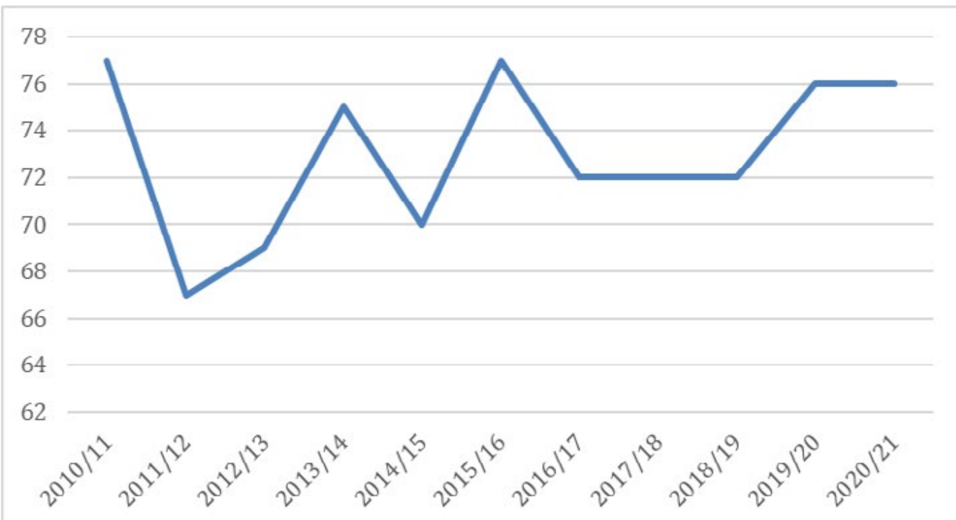
Union (UNICA, 2021) indicate that, in 2020, the area in Brazil used for sugarcane plantation was 8,616 million hectares, while in 2021, there was a decrease of 2.2% (8,422 million hectares). There are expectations of unprecedented growth in the production of both sugar and ethanol and energy (PETRINI, ROCHA and BROWN, 2017; OSAKI, 2019).

Brazil is a world leader in the production of sugarcane, about 657 million tons of sugarcane processed in the 2020/2021 (UNICA, 2021) harvest and its by-products: sugar, with 38 million tons, and the second largest producer of ethanol, with 35 billion liters. In this regard, Pereira (2017) states that Brazil is consolidated as the largest producer of sugar, while also holding second place in the production of ethanol, as well as in the use of technological innovation in this field, both in the industrial process and in the agricultural sector (Santos and Pinto, 2018).

The sugar-energy sector has shown stagnation in terms of productive efficiency per hectare (ha) in recent years (UNICA, 2021) as figure 1 shows.

Figure 1: Average productivity in Brazil between 2010/11 to 2020/21.



Source: Prepared by the authors based on UNICA (2021).

In this context, Zambianco and Rebellato, (2019) some innovation technologies and techniques are already used in the country for other cultures, such as soybeans and corn, to promote increased productivity per hectare, as well as cost reduction, for example, with the use of the precision agriculture system. Yet, their implementation has not been happening at the same pace when it comes to sugarcane planting (AMORIM *et al.,* 2019).

In this context, the importance of research covering sugarcane mills and suppliers is justified, analyzing the costs per hectare and per ton of sugarcane in the different strategies of soil preparation and planting systems of this culture, simultaneously, something which highlights the distinction and relevance of this study. Therefore, this research is positioned at the limit of knowledge on this topic in Brazil. In this sense, several papers were carried out, but they did not cover this theme as: (AMORIM, PATINO, and OLIVEIRA, 2019; AMORIM *et al.,* 2019; BARBOSA, 2018; PEREIRA, 2017; RAVELI, 2013, SANTOS *et al.*, 2018; ZAMBIANCO and REBELLATO, 2019).

So, is the price received per ton of sugarcane be sufficient to cover the costs of soil preparation and systems planting?

Essentially, there are four options for tillage: conventional tillage (CT), minimal tillage (MT), spot tillage (SP), and no-till (NT). What differentiates one system from the other is the type of machinery and equipment used to turn the earth (Barbosa, 2018). Therefore, the characteristics of each type of soil preparation are evidenced by the types of machines and equipment for each system.

In view of the above, the objective of this work is to analyze the costs of the combinations between the following four soil preparation techniques: conventional tillage (CT), minimal tillage (MT), spot tillage (SP), and no-till (NT) and the following planting systems: semi-mechanized planting (SMP), pre-sprouted seedling planting (PSSP), and mechanized planting (MP), between sugarcane mills and suppliers. Thus, we seek to answer the following question: Which systems, combined or individually, have the lowest cost (per hectare and per ton) of sugarcane under these conditions

2 LITERATURE REVIEW

Conventional tillage (CT) is carried out by tractors, harrows (intermediate and leveler), and subsoiler (or plow). Similarly, minimal tillage (MT) is also done with the use of tractors, subsoilers, and harrows. Spot tillage (SP), on the other hand, is carried out by tractors, subsoilers, and the use of rotary hoe. Finally, no-till (NT) only applies the use of tractors and subsoilers.

For each system of soil preparation, there are two options for correcting the pH and soil acidity: flat rate (FR): application of correctives uniformly throughout the area according to the average calculated through soil analysis; and the variable rate system (VR): application of correctives according to each point analyzed by a grid, or management zone.

Soil preparation is of paramount importance for the development of sugarcane. However, the development of this culture depends on the physical and chemical conditions of the soil. According to Amorim *et al.* (2019), this stage is one of the factors that most interfere with sugarcane productivity.

The most common types of planting in Brazil are: semi-mechanized planting (SMP), pre-sprouted seedling planting (PSSP), and mechanized planting (MP). For each type of planting, there are two options for distributing fertilizers, insecticides, and fungicides: flat rate and variable rate. Likewise, what differentiates one type of planting from another is the type of machinery and equipment used.

Semi-mechanized planting (SMP) is carried out by tractors, loader, implements, trucks, and need several people to operate the equipment (tractors, trucks) and also to distribute and chop the billets on the ground. Pre-sprouted seedling planting (PSSP), like SMP, also needs tractors and implements. This type of equipment performs several operations: furrows and plants, but it also requires labor to distribute the seedlings. Mechanized planting (MP), on the other hand, is done with tractors and planters, and this type of equipment can be both automated or operated with labor (Amorim, Patino and Oliveira, 2019).

The planting of sugarcane adopted by mills and suppliers varies according to the structure of machines and equipment that each one has and also the availability of labor. Nevertheless, there are some peculiarities for each type of adopted planting system, such as the age of the sugarcane seedling for MP, the slope of the terrain for SMP, and the fact that PSSP needs irrigation until the seedlings take root.

Amorim, Patino, and Oliveira (2019) understand that a distribution of seedlings outside the specified standard has a serious impact over the process of sugarcane, as it can compromise, due to a large number of failures, the lifecycle of the cane field.

According to Raveli (2013), the sugarcane minimal tillage (MT) system has a better overall quality of the operation for the indicators of furrow depth, seedling deposition failures, length of grinding wheels, total and damaged buds. Mechanized planting (MP), on the other hand, presents better quality for the groove spacing indicator.

3 MATERIALS AND METHOD

This is descriptive research with a quantitative approach, in which numerical data obtained through different soil preparation and sugarcane planting systems were statistically and comparatively analyzed.

3.1 Sample size

To define the sample size of plants and suppliers, the procedures were carried out as shown in equation 1:

$$n = N \times Z^2 \times p \times \frac{(1-p)}{Z^2} \times p \times (1-p) + e^2 \times (N-1) \quad (1)$$

where: n = sample size; N = population size; e = maximum estimation error (5%); z = value referring to the quantile of the 90% confidence distribution (1.65); and p = population proportion (0.03).

The study was carried out with mills and suppliers in the state of São Paulo, Brazil. The established number of mills was 31, being considered medium-sized powerplants.

The questionnaire was sent intentionally, through extensive use of relationship networks, in this case, the social network used were LinkedIn and WhatsApp Groups. However, it was verified whether the professional in the agricultural sector of the mills held any of the following positions: (supervisor of soil preparation and planting and/or agricultural manager). It was still verified whether the plant was classified as medium-sized, that is, a crushing capacity per harvest season between two and three million tons of sugarcane.

The number of suitable suppliers were those that produce more than 1,000 tons of sugarcane (approximately 12 hectares). Thus, the sample number was 42 suppliers.

With regard to sugarcane suppliers, the strategy was to contact two important sugarcane associations in the State of São Paulo: the Guariba Sugarcane Suppliers Association (SOCICANA) and the Cane Planters Association of the west part of the State of São Paulo (CANAOESTE). These two associations bring together more than 5,000 producers representing over 40% of the producers in this state.

In this way, a total of 73 surveys using closed questions with five alternatives were answered, provided data for the 2019/2020 season and, although the number is not significant in relation to the size of the population, it is understood as representative, as there are no studies registered with mills and suppliers that have obtained information on costs per hectare and per ton of sugarcane on soil preparation and planting for a sample larger than that achieved in this work.

All participants consented to the Free and Informed Consent Term - Prepared based on Resolution No. 466/2012, of the Ministry of Health and on the guidelines of the Research Ethics Committee of the State University of Campinas - UNICAMP, approved the project of the research, no. 1,885,220, no. CAAE: 58212716.0.0000.5404. Among the conditions for sending the questionnaire, the anonymity of the participants is an item to be respected. In this case, the names of the sugarcane mills, the suppliers and their respective managers are not mentioned in this research.

3.2 Data analysis

Ten questions were analyzed, one of them referring to the average (in ton) of sugarcane produced per hectare, and the others referring to the costs of soil preparation and planting, considering the following variables:

Mechanization of soil preparation - limestone and gypsum application, terracing, harrowing, subsoiling, plowing, and support structure.

Mechanization of planting - furrowing, covering, cutting seedlings, transport, herbicide application, manual support structure, and labor for transportation.

Preparation inputs - herbicide, limestone, gypsum, phosphate.

Planting inputs - amount of seedlings used per hectare, fertilizers, fungicides, and insecticides.

Labor for soil preparation - operators, drivers, soil sampling, supervisors, leaders, topography assistant, etc.

Labor for planting - operators, tractor driver, driver, general services.

The main types of soil preparation and planting (individual) that have a percentage greater than 5% representativeness were analyzed. Regarding the combinations of systems (soil preparation and sugarcane planting), a pattern was established considering only those that had a percentage above 10% of representativeness in the sum of both.

The cumulative frequency generated from the Monte Carlo (MC) method in the Oracle Crystal Ball software (an extension of Microsoft Excel) was used, in order to provide projections through a stochastic approach and to analyze the probability (or level of certainty) of occurrences at certain costs or average profits.

The MC method is a numerical method that uses random numbers to solve mathematical problems for which an analytical solution is not known. The lower and upper values used in the intervals were obtained from the standard deviation calculated in the descriptive analysis of the MC method, in order to identify the level of probability of occurrence of the costs of plants and suppliers from the cumulative distribution.

Second Silva *et al.* (2019), the input variables that support the simulation are called 'assumptions' by Crystal Ball. All assumptions were made using the normal distribution. The choice for the normal probabilistic model was due to the low dispersion of the values presented in the descriptive analysis of the MC method. In this way, the possible values for the variable of interest are simulated using resampling, and then, the average result of the process is obtained through the following equation:

$$a_m = \frac{1}{n}\sum_{i=1}^{n} x_i, \quad (1)$$

where a_m = the average result of the MC method for the variable of interest a; x = the individual result of each simulated iteration; and n = the number of simulations (iterations).

Thus, 50,000 iterations were performed, which is the maximum number of iterations made available by the software and that is believed to be a relevant value for the problem of interest. The number of identical iterations was used in work of AMORIM *et al.* (2019).

Soil preparation costs per ton of sugarcane (SPC_TS) were calculated using equation 2:

$$SPC\_TS = (TC\_ST \div PROD) \quad (2)$$

where TC_ST = total cost of soil preparation per hectare, and PROD = productivity per hectare.

The planting costs per ton of sugarcane (PC_TS) were calculated using equation 3:

$$PC\_TS = (TC\_PL \div PROD) \quad (3)$$

where TC_PL = total cost of planting sugarcane per hectare, and PROD = productivity per hectare.

The total cost of the sugarcane field (TC.cycle) was calculated through equation 4:

$$TC.cycle = \sum(C\_SP + C\_PL + C\_CT + C\_CLT) \quad (4)$$

where C_SP = cost of soil preparation; C_PL = cost of planting; C_CT = cost of cultural treatments (US$ 458.67/hectare × 4 (Socicana, 2021)); and C_CLT = cost of cutting, loading, and transport (US$ 7.85/ton × 5 (Socicana, 2020).

The C_CLTs vary according to the average productivity mentioned by each group throughout the cycle (5 harvests). However, the values per ton were fixed for an average distance of 25 km between rural properties and sugar mills, with an average value of US$7.85, according to (Socicana, 2021).

The C_CTs were fixed, US$458.67 per crop, being multiplied by four (4), as the supplier and the mills are expected to carry out four cultural treatment operations throughout their production cycle (Socicana, 2021). The monetary values of the TC_SP and TC_PL were converted into dollars using an exchange rate of US$1.00 = R$5.25.

4 RESULTS AND DISCUSSIONS

The costs arising from the main combinations of soil preparation and planting systems used by sugarcane suppliers and mills, considering variable rate are presented in table 1. These results showed that the lowest cost per ton was obtained through conventional tillage and mechanized planting (suppliers). It is worth mentioning that suppliers had lower costs per hectare in the combination of the systems of soil preparation and planting in relation to the mills in 5.8%. In relation to the percentage of the Total Cost of soil preparation and planting, the obtained values were: 19.1% for suppliers and 20.9% for mills, respectively. In terms of cost per ton, suppliers had a 5.3% lower cost compared to mills.

The variable rate system is seen as a technological innovation in the sugar-energy sector. In this case, the use of technology such as GPS, different types of tractors and rational agricultural machines and consequently, their power, can be the difference in the impact of suppliers and mills, in this case.

Table 1. Costs of soil preparation and planting using variable rate (SPPLVR) in US$.

Acronym	C_SPPL	C_CLTs	C_CTs	TC cycle	CTS
CTSMP (1)	-1.323	-3.555	-1.834	-6.713	-14,7
CTMP (1)	-1.237	-3.594	-1.834	-6.666	-14,5
Average	**-1.28**	**-3.574**	**-1.834**	**-6.689**	**-14,6**
CTSMP (2)	-1.349	-3.242	-1.834	-6.426	
CTMP (2)	-1.360	-3.321	-1.834	-6.516	-15,4
Average	**-1.355**	**-3.281**	**-1.834**	**-6.471**	-15,2
Overall Average	**-1.3573**	**-3.301**	**-1.834**	**-6.493**	**-15,3**

Description: Cost of soil preparation and planting (C_SPPL); Cost of cutting, loading, and transport (C_CLTs); Cost of cultural treatments (C_CTs); Total Cost of the sugarcane field (TC cycle); Costs per ton of sugarcane (CTS) between sugarcane suppliers (1) and mills (2). CTSMP = conventional tillage and semi-mechanized planting; CTMP = conventional tillage and mechanized planting.
Source: Prepared by the authors.

The costs through the combinations of soil preparation and sugarcane planting between mills and suppliers using fixed rate is described in table 2.

Table 2. Cost of soil preparation and planting with fixed rate (SPPLFR) in US$.

Acronym	C_CLTs	C_CTs	C_SPPL	TC.cycle	CTS
CTSMP (1)	-3.452	-1.834	-1.247	-6.533	-14,8
CTPSSP (1)	-3.688	-1.834	-1.283	-6.647	-14,8
CTMP (1)	-3.531	-1.834	-1.283	-6.647	-14,8
MTMP (1)	-3.452	-1.834	-1.188	-6.474	-14,7
MTSMP (1)	-3.374	-1.834	-1.192	-6.400	-14,8
NTMP (1)	-3.413	-1.834	-1.188	-6.435	-14,8
NTSMP (1)	-3.335	--1.834	-1.223	-6.521	-14,8
Average	**-3.464**	**-1.186**	**-6.354**	**-15.0**	**CTSMP**
CTSMP (2)	-3.217	-1.834	-1.755	-6.781	-16,6
CTMP (2)	-3.256	-1.834	-1.535	-6.654	-16,0
SPMP (2)	-2.864	-1.834	-1.219	-5.816	-16,0
SPSMP (2)	-2.825	-1.834	-1.422	-5.932	-16,6
Average	**-3.040**	**-1.834**	**-1.421**	**-6.296**	**-16,2**
Overall average	**-3.310**	**-1.834**	**-1.324**	**-6.408**	**-15,4**

Description: Cost of soil preparation and planting (C_SPPL); Cost of cutting, loading, and transport (C_CLTs); Cost of cultural treatments (C_CTs); Total Cost of the sugarcane field (TC.cycle); costs per ton of sugarcane (CTS) between sugarcane suppliers (1) and mills (2). CTSMP = conventional tillage and semi-mechanized planting; CTPSSP = conventional tillage and pre-sprouted seedling planting; CTMP = conventional tillage and mechanized planting; MTMP = minimal tillage and mechanized planting; MTSMP = minimal tillage and semi-mechanized planting; NTMP = no-till and mechanized planting; NTSMP = no-till and semi-mechanized planting; SPMP = spot tillage and mechanized planting; SPSMP = spot tillage and semi-mechanized planting.
Source: Prepared by authors.

The suppliers obtained a lower cost/ton in all combinations when compared to the mills, with the highlight being conventional tillage and mechanized planting (suppliers). Thus, the difference between this system and the lowest sugarcane cost/ton values at the mills were 9.1%.

The results in these combinations showed that the suppliers' costs per ton are lower than those of the mills. The percentage representing the Cost of cutting, loading, and transport (C_SPPL) under the Total Cost is 18.8% for suppliers and 22.6% for mills. More significant results were evidenced in the difference between the percentage of profit/ton of sugarcane for suppliers and mills, which is 61.5%.

Table 3 shows costs of soil preparation with variable rate and planting with fixed rate Cost of soil preparation with variable rate and planting with fixed rate and variable rate combinations between mills and suppliers.

Regarding the lower cost/ton, the suppliers had a lower Average Total Cost (ATC) when compared to the mills. On the other hand, the lowest individual cost referring to the ATC and Cost of cutting, loading, and transport was the combination of spot tillage and mechanized planting, spot tillage, and mechanized planting (mills). This system had an (ATC) of 12.3% lower than the (ATC) of the suppliers. In relation to the Cost of cutting, loading, and transport (C_SPPL), the difference was 14.1%. The percentage representing the (C_SPPL) under the Total Cost is 19.5% for suppliers and 21.6% for mills.

Table 3. Costs (US$ per ton) of soil preparation with variable rate and planting with fixed rate (SPVRPLFR).

Acronym	C_CLT	C_CTs	C_SPPL	TC.cycle	CTS
CTSMP (1)	-3.452	-1.834	-1.293	-6.579	14.7
CTMP (1)	-3.531	-1.834	-1.288	-6.653	14.3
Average	**-3.491**	**-1.834**	**-1.290**	**-6.616**	**14.5**
CTSMP (2)	-3.217	-1.834	-1.4084	-6.459	17.2
CTMP (2)	-3.256	-1.834	-1.564	-6.654	18.8
STMP (2)	-2.864	-1.834	-1.109	-5.807	15.2
STSMP (2)	-2.825	-1.834	-1.274	-5.933	17.7
Average	**-3.0340**	**-1.340**	**-1.334**	**-6.236**	**17.2**
Overall average	**-3.265**	**-1.834**	**-1.314**	**-6.426**	**15.8**

Description: Cost of soil preparation and planting (C_SPPL); Cost of cutting, loading, and transport (C_CLTs); Cost of cultural treatments (C_CTs); Total Cost of the sugarcane field (TC.cycle); Costs per ton of sugarcane (CTS) between sugarcane suppliers (1) and mills (2). CTSMP = conventional tillage and semi-mechanized planting; CTMP = conventional tillage and mechanized planting; STMP = spot tillage and mechanized planting; STSMP = spot tillage and semi-mechanized planting.
Source: Prepared by the authors.

Table 4 shows the combination costs of soil preparation with fixed rate and planting with variable rate for mills and suppliers. Regarding the lowest cost/ton, Average Total Cost, and cost of soil preparation and planting, suppliers were more efficient when compared to mills by 7.7%, 1%, and 22.2%, respectively. The percentage representing the (C_SPPL) under the Total Cost is 19.5% for suppliers and 23.5% for mills.

Table 4. Costs (US$ per ton) of soil preparation with flat rate and planting with variable rate (SPFRPLVR).

Acronym	C_CLTs	C_CTs	C_SPPL	TC.cycle	CTS
CTMP (1)	-3.476	-1.834	-1.281	-6.591	14,8
CTMP (2)	-3.256	-1.834	-1.565	-6.655	16,0
Overall average	**-3.366**	**-1.834**	**-1.423**	**-6.573**	**15,4**

Description: Cost of soil preparation and planting (C_SPPL), Cost of cutting, loading, and transport (C_CLTs), Cost of cultural treatments (C_CTs), total cost of the sugarcane field (TC.cycle); costs per ton of sugarcane (CTS) between sugarcane suppliers (1) and mills (2). CTMP = conventional tillage and mechanized planting.
Source: Prepared by the authors.

Furthermore, the results of this research proved that the cost per ton of sugarcane is directly correlated with sugarcane productivity per hectare. The results presented here corroborate those of De Amorim *et al.* (2019) they emphasize that the precision agriculture method has higher productivity in volume for converting sugarcane into sugar.

From another perspective, Pereira (2017) emphasizes that each type of soil preparation and planting system has its strengths and weaknesses, and that each *locus* must obey its particularities, that is, each region adapts better to a particular combination of cropping systems, soil preparation, and planting that will result in increased productivity. In this sense, Santos *et al.* (2018) state that evaluating and understanding production costs is of paramount importance for the management of rural properties.

Table 5 shows the statistical results obtained through the Monte Carlo method, referring to the costs per ton of sugarcane.

Table 5. Statistical results referring to the costs per ton of sugarcane (CTS) obtained from the Monte Carlo (MC) method.

	Sets of Soil Preparation and Planting			
Type	**SPPLVR**	**SPPLFR**	**SPVRPLFR**	**SPFRPLVR**
Level of certainty	68.0%	68.4%	68.2%	68.3%
Coefficient of variation %	-0.05%	-0.03%	0.04%	0.07%
Standard deviation (US$)	0.75	0.46	0.67	1.09
Medium (US$)	14.95	15.33	16.32	15.40
Maximum (US$)	17.90	17.25	19.20	19.81
Minimum (US$)	11.70	13.57	13.53	10.54
Variance	0.56	0.21	0.45	1.20

Description: SP = soil preparation; PL = planting system; SPPLVR = soil preparation and planting with variable rate; SPPLFR = soil preparation and planting with fixed rate; SPVRPLFR = soil preparation with variable rate and planting with fixed rate; SPFRPLVR = soil preparation with flat rate and planting with variable rate.
Source: Prepared by the authors.

Such results provided information based on the average cost between mills and suppliers. In this way, they can minimize uncertainties and support the decisions of these stakeholders in choosing the best combination of systems to be used for soil preparation and sugarcane planting, considering: the availability of machines, equipment, labor, and capital.

The results show that the level of probability does not differ significantly, as well as the percentage of the coefficient of variation that were considered as low dispersion. The smallest costs per ton of sugarcane among the soil preparation and planting with variable rate combinations differs from the system with the smallest soil preparation and planting with fixed rate variance.

The price of a ton sugarcane in the survey year US$ 13,71, second Nation bioenergy Union (UDOP, 2021), thus all soil preparation and systems planting combinations are higher than the values received per ton of sugarcane. Therefore, the results corroborate the statement of Martins *et al.* (2018) nowadys, the organizations are facing a much more agile and competitive environment, demanding new techniques of competition, and new production models.

5 CONCLUSION

The guiding question of this study for the literature was the possibility of analyzing costs the costs per hectare and per ton of the sugar production sugarcane related to soil preparation and systems planting sugarcane.

There is a considerable difference in production costs that the larger the scale of production the greater the difference in final production costs.

The main contribution of this research to the area of costs is to verify that the lowest cost hectare considering the possible combinations between soil preparation and planting systems, the combination spot tillage with mechanized planting with fixed rate for mills, stood out with US$1,109. The lowest cost per ton was the combination conventional tillage with variable rate and mechanized planting with flat rate for suppliers, displaying a value of US$14.30.

In addition, a limitation of this research is evidenced by the sample concentration. As a suggestion for future work, it is recommended to develop collection instruments so that the responses to the variables are not categorized. In addition, it is suggested that data from other sugarcane producing regions in Brazil with greater representation, such as the states of Minas Gerais, Paraná, Goiás, and Mato Grosso do Sul. As a form of data analysis and comparison using cluster analysis.

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