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Impact of harvesting with burning and management of straw on the industrial quality and productivity of sugarcane

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Change from the traditional harvesting system with burns to mechanized harvesting of sugarcane, as well as the amount of straw needed to remain in the field for sustainability of the production system and how much could be removed for sectors such as energy cogeneration and bioethanol production, are not clarified issues. The objective of this study was to evaluate the impact of harvest management with burning (traditional) and cultivatation with different amounts of straw on the industrial quality and productivity of sugarcane. The effect of six treatments were evaluated: cane burning, 0, 25, 50, 75 and100% (20 Mg ha^{-1}) of straw on the industrial quality (soluble solids (°Brix), Pol, apparent purity, total sugars (TS), reducing sugars (RS) and fiber) and productivity (Mg Pol ha^{-1}) of sugarcane. At the end of the cycle, the straw decomposition rate for each treatment was also verified. The higher the percentage of straw, the higher the degradation rate. The change of burned cane harvesting system for sugarcane under straw results in improved productivity of sugarcane and favors the production of sugar. The straw and harvest system change do not affect the industrial quality of sugarcane. The harvest with burning, the total withdrawal or of 75% of the straw of the field result in lower productivity. The maintenance of 50% of the straw on the soil surface is sufficient to improve the productivity of sugarcane in dry period, and the remaining 50% can be used for second generation of ethanol production or electricity without damaging the crop productivity.

Key words: *Saccharum* spp, soil cover technological quality, biomass, sucrose.

INTRODUCTION

The major sugarcane producing areas of world have recently adopted the practice of mechanical harvesting and this practice tends to increase both in current areas and in expansion (Braunbeck; Magalhães, 2010).

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In this system, large amount of straw is produced. It is estimated that each year, more than 300 million Mg of straw are produced (UNICA, 2015). In the field, values are found to be from 10 to 30 Mg ha^{-1} of dry straw, oscillating because of the variety and age of the cane field (Christoffoleti et al., 2007).

This amount of plant material that remains in the soil, causes changes in the chemical, physical and biological conditions of the agricultural environment, such as increased soil moisture (especially important in areas with water deficit), elevated levels of organic matter, changes fertility and temperature in the surface layers of the soil, greater efficiency in the control of erosion, changes in incidence of light on the soil surface, budbreak in irregularity under straw with a possible decrease in productivity of varieties susceptible to straw (Silva et al., 2003; Christoffoleti et al., 2007; Cavenaghi et al., 2007; Guimarães et al., 2008).

The industrial quality and productivity of sugarcane are strongly influenced by changes in the production environment. Marques and Pinto (2013) reported that some soil characteristics such as porosity, storage capacity of water and evaporation, can be altered to promote positive change in factors of production, and the use land cover is a technique to promote these changes.

The benefits obtained with the straw surface have been reported by several authors, although not accosted what quantity would be sufficient to achieve these improvements. Quantification of straw needed to promote these benefits is essential information for the sustainability of the sugarcane production system and to optimize the energy generation sector, enabling the excess of straw can be used for the production of bioethanol and/or bioelectricity, which play an important role in the global energy grid. It is estimated that the use of straw can triplicate the ethanol production without the need to increase the planting area, once one ton of straw results in 270 liters of ethanol, and one ton of sugarcane results in 80 L of ethanol (Santos et al., 2012). Thus there is a concern to determine the required amount of straw that should remain in the field, in order to provide greater crop protection and soil.

Importantly, in addition to contributions on soil fertility already described (Franchini et al., 2001 Resende et al., 2006), the straw as cover also plays an important role in environmental protection, from the point of view of soil conservation. However, several producing countries still use as a traditional method, the harvesting system of sugarcane with straw burning. Soil degradation is currently considered one of the most serious environmental problems. Erosion is a form of most harmful degradation, since it reduces irreversibly the productive capacity of the cultures, besides causing sedimentation and pollution of water supplies. According to Braunbeck and Magalhães (2010), the straw cover protects the soil in all phases of the erosion process because it absorbs the kinetic energy of the rain drops, decreases the speed of runoff and hinders displacement of the particles. Thus, maintenance of stubble on the surface is a management of great importance when seeking the sustainability of the sugarcane production system.

Considering these aspects, the aim of this study was to evaluate the effect of harvest management with burning (traditional) and cultivation with different amounts of straw in industrial quality and productivity of sugarcane.

MATERIALS AND METHODS

The experiment was implemented at the Bandeirantes Sugar and Alcohol Processing Plant, located in the municipality of Bandeirantes, Parana State, Brazil, at 23° 06' S latitude and 50° 21' W longitude, and at 440 m above the sea level. The annual average precipitation is 1.300 mm and the annual average insolation is 7.14 $h.day^{-1}$. The soil is classified as Rhodic Eutrudox (Embrapa, 2013) of clay texture, with 61% clay; 2% silt and 37% sand.

The installation of the experimental area was in August of 2010 when chemical analysis was performed on soil (Embrapa, 1997) layers ranging from 0–0.10; 0.10–0.20; 0.20–0.40; and 0.40–0.60 m in profile depth (Table 1). There was no need for chemical fertilization, but 70 Mg ha^{-1} of sugarcane filter cake was spread over the entire area previously for the implementation of the trial. The soil was prepared by using heavy and then light disc harrow.

The climatological hydric balance of the area (Figure 1) was calculated based on Thornthwaite and Mather (1955). Normal average monthly temperatures and total monthly rain data were provided by the meteorological station of the Parana State Agronomical Institute (IAPAR), located also in Bandeirantes, PR, 3 km from the experimental location. As available water capacity value (AWC) in the soil, 100 mm was used for hydric balance calculation. In the experimental area, sugarcane had been grown for 65 years, using manual harvesting with straw removal by burning. In 2010, the sugar mill plant adopted the mechanized harvesting system without straw burning, which was also used at the experimental site.

The experiment was conducted during the course of two sugarcane crop cycles, with the SP801816 cultivar (first and second ratoon) in a randomized block design with four replications. Each plot "consisted of" 10 rows of sugarcane, 10 m in length (10 rows x 10 m) and 1.50 m between rows. For evaluations, 6 central rows of 9 linear meters each, with a total of 54 linear meters were considered.

The variety of sugarcane used was SP 80-1816, a more widespread in the South Central of Brazil, due to its good tillering and regular closing lines, high agricultural productivity, good budding ratoons, early maturing, high content sucrose, low fiber content, tipping and flowering absence (Fernandes, 1991).

The following treatments were evaluated: 0, 25 (5 Mg ha^{-1}), 50 (10 Mg ha^{-1}), 75 (15 Mg ha^{-1}) and 100% (20 Mg ha^{-1}) of straw on the soil, and burned sugarcane (where 100% of the straw was burned). The industrial quality components evaluated were: juice soluble solids (°Brix), Pol (%), total sugars (TS), apparent purity (%), reducing sugars (RS) and fiber.

In August 2010, immediately after planting, quantities of straw of each treatment were added to the soil. The straw deposition in the plots was obtained in another area, after the mechanical harvesting of cane plant of the same variety. In this area, plots of the same size of the experimental area were demarcated and they contained straw wrapped in bags, weighed and redistributed on the plots in the respective amounts of each treatment. To evaluate the dry matter of straw produced by the variety, 1 m^2 was measured immediately after the harvest, and all the straw contained in this

Table 1. Results of the chemical analysis of soil Rhodic Eutrudox at depths of 0 to 0.60 m, city Bandeirantes - PR, 2010.

Depht (m)	M.O	pH	P	K	Ca	Mg	H+Al	SB	CTC	Ca	Mg	K
	g kg^{-1}	$CaCl_2$	mg dm^{-3}	Cmol$_c$ dm^{-3}						% Saturation		
0 – 0.10	26.8	5.4	8.6	2.50	7.8	1.7	3.1	12.0	15.1	51.6	11.2	16.5
0.10 – 0.20	41.6	5.9	71.3	3.60	7.9	1.9	2.9	13.4	16.3	48.5	11.7	22.1
0.20 – 0.30	34.9	6.1	31.0	3.70	8.0	2.1	3.0	13.8	16.8	47.6	12.5	22.0
0.30 – 0.40	30.9	6.2	5.1	4.60	8.1	2.1	2.2	14.8	17.0	47.6	12.3	27.0
0.40 – 0.50	37.6	6.3	9.0	4.20	7.3	2.0	2.4	13.5	15.9	45.8	12.6	26.4
0.50 – 0.60	28.2	6.3	5.3	3.20	6.1	2.1	2.4	11.4	13.8	44.2	15.2	23.1

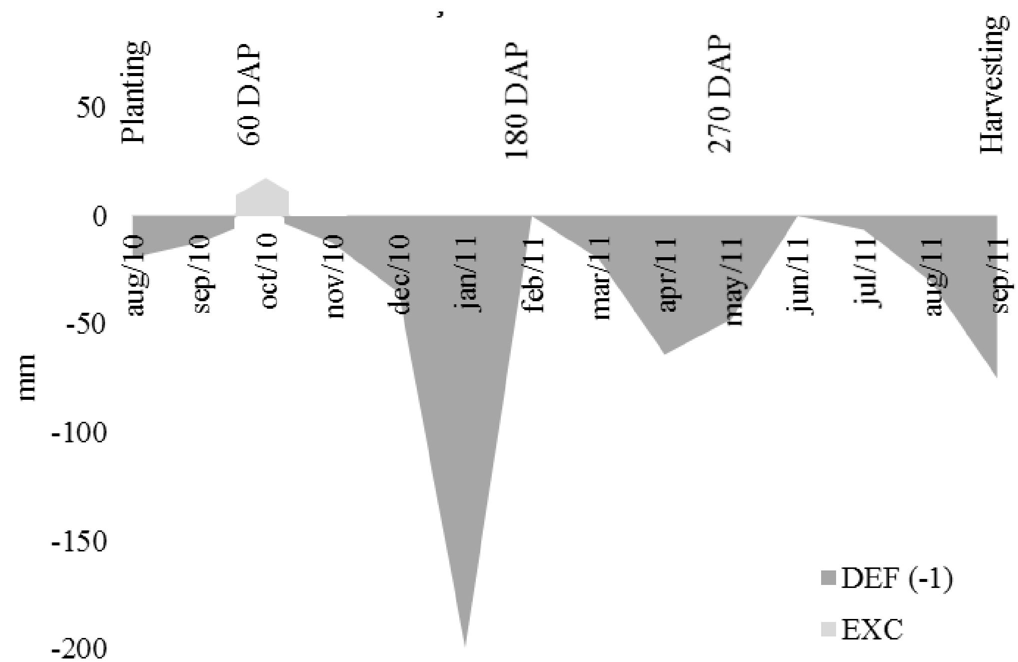

Figure 1. Extract of the monthly water balance during the experimental period.

area were removed, kiln dried and weighed. This procedure was performed in 48 repetitions. The percentage of decomposition of straw was evaluated at the end of the cycle, the DAC 360, in 12 replicates per treatment, by weighing the straw contained in 1 m^2. These samples were collected randomly in the plot and kiln dried until constant weight.

At the end of the cycle, at 360 DAP to determine the industrial quality, ten stems of sugarcane were harvested

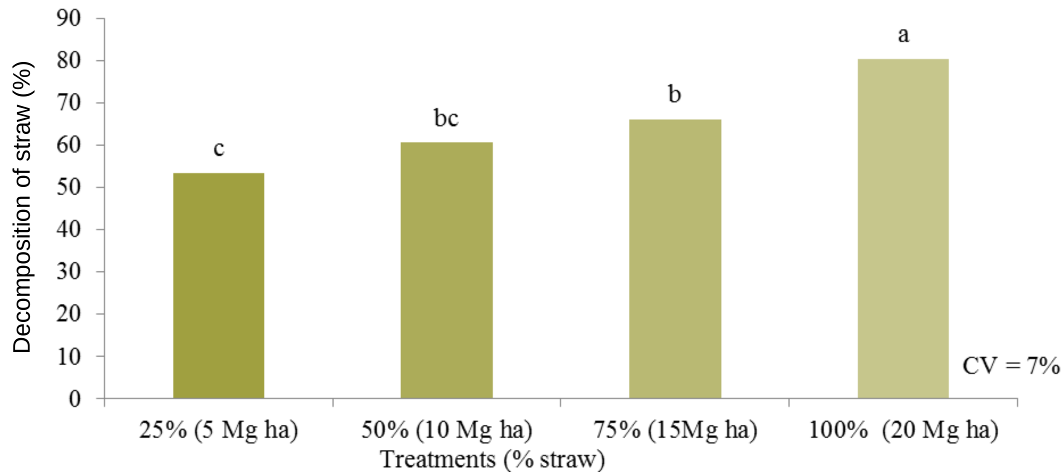

Figure 2. Decomposition rate of the straw for treatments 25 (5 Mg ha^{-1}), 50 (10 Mg ha^{-1}), 75 (15 Mg ha^{-1}) and 100% (20 Mg ha^{-1}) of straw, at the end of the crop cycle in August of 2011. Means followed by the same letter are not significantly different by Duncan test at 1% significance level.

from each plot after the green and dried leaves had been removed, and then the topping was performed. The samples were immediately sent to the quality control laboratory of the sugarcane mill and they were analyzed according to the methodology of CONSECANA (2006).

The productivity evaluation (Mg Pol ha^{-1}) was performed at 400 DAP (September 2010) and obtained by the formula $Productivity = (Mg\ sugarcane\ ha^{-1} \times Pol_{cane})/100$ (Silveira et al., 2012). The production of sugarcane in Mg per hectare was obtained through the harvesting and weighing of all stalks contained in the plots.

The data were analyzed by variance analysis (ANOVA) and the averages were compared by the Duncan test (P<0.05 and 0.01). The software Sisvar 5.3 (Ferreira, 2010) was used for the analyses.

RESULTS AND DISCUSSION

The average production of straw for SP80-1816 cultivar was 20 Mg ha^{-1}. Figure 2 is the percentage of decomposition of the straw at the end of the crop cycle (360 days). It can be seen that higher values were obtained with 75 treatments and 100% (15 to 20 Mg ha^{-1}, respectively) of straw, reaching respectively, decomposition rate of 75 to 80%. Note also, that smaller amounts of straw (25 and 50%) showed the lowest rates of decomposition, 53 and 61%, respectively. This can be explained by the fact that the presence of higher amount of straw on the surface, provides maintenance of higher moisture and lower thermal fluctuation (Tavares et al., 2010) particularly in the superficial layers, favoring the water cycle and nutrients (Freitas et al., 2004). Thus, the greater the amount of straw on the soil, the more moisture retained therein, creating a microclimate that favors the proliferation of fungi and more rapid decomposition of the material (Glória et al., 2000). Oliveira et al. (1999) in system under irrigation, also reported 80% reduction in the mass of dry straw after weighing at the beginning and after 11 months in the field, corroborating results obtained in this study. In relation to industrial quality of juice components, the following averages were obtained: Soluble solids: 21 °Brix, Pol: 17%, pureza aparente: 84% and TS: 145 kg Mg^{-1} (Figure 3).

Fernandes (2000) considered 14.4 °Brix as an "adequate" amount of soluble solids for the beginning of the harvest. The purity of the juice must be over 80% in the beginning, and 85% throughout the rest of the harvest. It was observed that, no matter how treatments were employed, the cultivar showed values above those cited as good, and "it is considered as a rich cultivar of sucrose". The average value of RS was 0.9%, according to the results found by Souza et al. (2005), evaluating the management of cane harvested with and without burning and found that AR values were below 1.0%. The average fiber content was 13% (Figure 3), a value slightly above the average standard considered, that is 12.5% (Fernandes, 2000), probably due to the long period of low water availability faced during the cycle.

The change of sugarcane harvesting system with burning for 65 years for the management system with different amounts of straw did not interfere with industrial quality components juice (soluble solids (°Brix), Pol, TS, purity, RS and fiber) indicating good adaptation of the plant.

These results confirm those obtained by Resende et al. (2006) evaluatingthe effect of straw, after 16 years of cultivation on industrial quality of sugarcane and observed that the maintenance of straw for system did not affect the soluble solids values (Brix), Pol, fiber, purity and percentage of sugar juice. However, Souza et al. (2005) found a reduction of ST and apparent sucrose of ratoon sugarcane harvested without burning, 18 varieties of sugarcane, when incorporated up to 70% of the straw

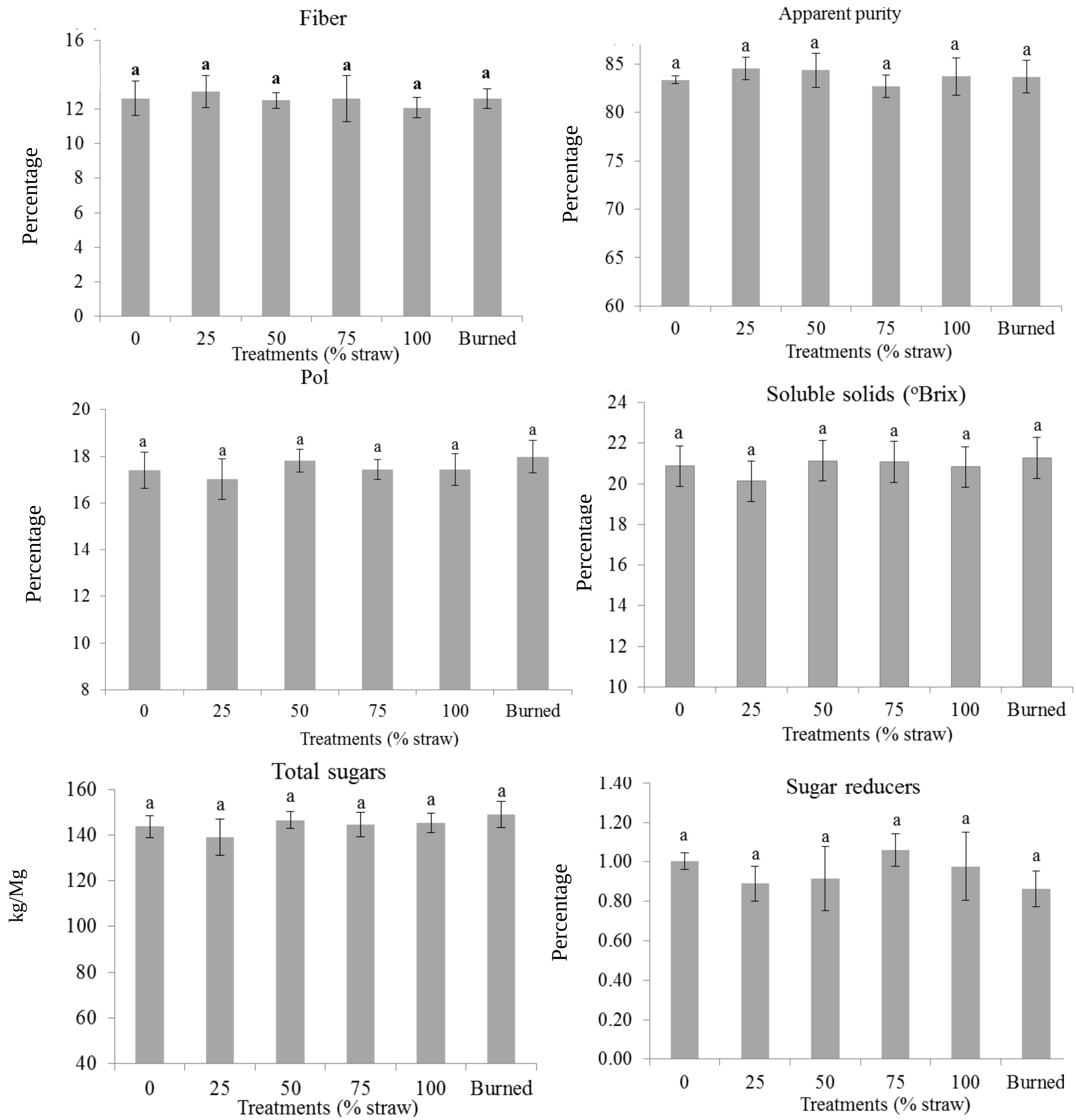

Figure 3. Fiber (%), apparent purity of juice (%), Pol (%), soluble solids (°Brix), total sugars (kg Mg^{-1} of sugarcane) and sugar reducers (SR%) of sugarcane in relation to the amount of straw surface. Means followed by the same letter are not significantly different by Duncan test at 5% significance level.

at a depth of 0 to 0.30 m, emphasizing the importance of knowledge of the effects of different managements of straw to maintain a high crop yield with satisfactory quality.

There was a significant effect of management of straw on productivity (Mg Pol ha^{-1}). The harvest with burned

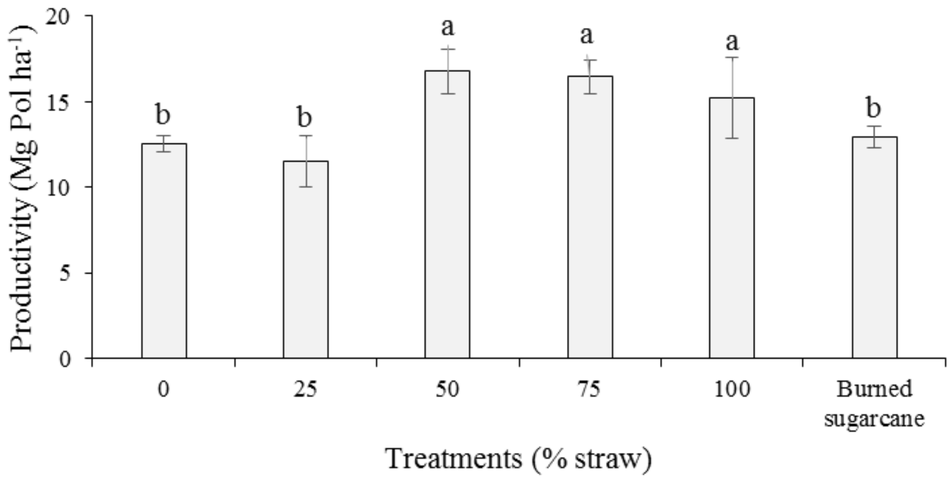

Figure 4. Production of sugarcane (Mg Pol ha^{-1}) in relation to the amount of straw surface (%). Means followed by the same letter are not significantly different by Duncan test at 1% significance level.

cane has resulted in 20% lower productivity (12.95 Mg Pol ha^{-1}) than the treatments of 50, 75 and 100% straw (average of 16.16 Mg Pol ha^{-1}) (Figure 4). Comparing between treatments without burning, the quantities of 50, 75 and 100% of straw did not differ (average of 16.16 Mg Pol ha^{-1}) and provided average 25% increase in productivity when compared with soil treatment discovered (0%) and 25% of straw (12.56 and 11.53 Mg Pol ha^{-1}, respectively). Thus, it is observed that although there was no influence of treatments on components of industrial quality, production of sugar was favored by higher crop productivity in quantities above 50% straw.

The significant result of straw in the first year of cultivation should probably prolong drought in this period, with rainfall below the historical average causing water deficit of up to 200 mm (Figure 1), which resulted in low productivity of sugarcane plantations all over the south-central Brazil, down 11.20% (CONAB, 2015). It can be seen that only in October, at 60 DAP were greater water available (Figure 1), thus affecting the initial growth stages, essential period that cause adequate supply of water for the development of crops. The damage to the plant and stem productivity due to periods of water stress are greater when it occurs in the early stages of culture, it can hinder or delay the development of aerial part. When it occurs in the other phases, the sugarcane productivity is rarely affected (Inman-Bamber and Smith, 2005). Water deficit reduces gas exchange and its conduction to the leaves. When the hydric deficit is interrupted, the gaseous exchanges tend to go back to normal, however, at a slower rate, which can compromise the crop production during the entire cycle (Silva and Pincelli, 2010).Braunbeck and Magalhães (2010) emphasized that the straw provides reduction in soil water loss of approximately 70%, and reduction in the average temperature of the surface soil layers, and an increase of organic matter, favoring not only the largest structure of soil microbiota, but also increasing the root system (Aquino et al., 2016) crop yield.

It was observed in this study, that there are different answers to culture in accordance with the amount of straw that remains in the field. This is particularly important if one considers that, recently, the use of this waste for second generation ethanol and bioelectricity production has been one of the main alternatives to supply of the increasing global demand for this type of energy, causing doubts about what amount required to be maintained the field to guarantee the sustainability of the sugarcane production system.

It can be seen in this study that 50% of straw was sufficient to provide increased crop productivity in drought cycle and above that amount there was no statistically significant difference. It was also observed that the removal of 75% of soil straw resulted in decreased productivity (Mg Pol ha^{-1}) not differing from the treatments where the soil was discovered (0% straw and burned cane). Thus, it appears that the maintenance of straw in the system is essential for the productivity of sugarcane, the system sustainability and sugar production.

Conclusions

1. The higher the percentage of straw, the greater the degradation rate.
2. The change of burned cane harvesting system for sugarcane under straw results in improved productivity of sugarcane favors the production of sugar.
3. The industrial quality of sugarcane is not affected by the straw and harvest system change.

4. The harvest with burning, the total withdrawal or of 75% of the straw of the field result in lower productivity.
5. The maintenance of 50% of the straw surface is sufficient to improve productivity.

Conflict of Interests

The authors have not declared any conflict of interests.

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