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Sugarcane straw management and its impact on production and development of ratoons

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ABSTRACT

Due to mechanical harvesting large amount of straw is left in the field which implicates modification throughout the agriculture environment. This straw is beneficial for both soil and plant. However, there is no information about the sufficient quantity which can be used to achieve such effects and also whether it can be used in other sectors like electricity and ethanol production. Therefore, a research was designed with the objective to evaluate the effect of different amounts of straw on the development and productivity of sugarcane during the first and second ratoons. Treatments used in the experiment included: burned cane, 0%, 25%, 50%, 75% and 100% (20 t ha^{-1}) of sugarcane straw left on the soil surface. The tested variables included leaf area index (LAI), number, diameter, length and production of stems. Plants were evaluated at 60, 120, 180, 240 and 370 days after harvest (DAH) for the first ratoon and at 60, 120, 180, 240 and 270 DAH for the second ratoon. Replacing burned cane harvest system for soil management with straw promotes the development and productivity of sugarcane ratoons. Field managements with burned cane, total removal of the straw, or keeping 25% of straw result in low number of tillers, leaf area index, stem diameter and productivity of sugarcane ratoons, under water stress conditions. Whereas keeping 50% of straw mulch is enough to improve the growth and yield of sugarcane with drought occurrences, while the remaining 50% can be used for second generation of ethanol production or electricity without damaging the crop yield.

1. Introduction

Sugarcane (*Saccharum* spp.) is grown in over 121 countries and is a good source for the production of sugar and ethanol. Over 80% of the sugar produced in the world is obtained from sugarcane, whereas Brazil, India, China and Thailand account for 60% of the total production (FAO, 2016). The major sugarcane producing areas of world have recently adopted the practice of mechanical harvesting (Cardoso et al., 2013; Unica, 2015). In this system, dry leaves, tips and green leaves are cut off and thrown on the soil surface forming a straw that acts as mulch over soil surface. In Brazil between 10 to 30 Mg ha^{-1} of straw is left in the field after harvest, depending on the variety and age of the sugarcane field (Oliveira et al., 2003). More than 300 million Mg of straw is produced per year worldwide (Unica, 2015).

This layer of plant residue over the soil surface is very useful for the production system, promoting better water infiltration into the soil, stabilizing the temperature and lowering the evaporation from surface layer, altering of light incidence to the surface, better control of erosion, increase in the organic matter contents of the soil and improvement of soil structure (Inman-Bamber and Smith, 2005; Garcia et al., 2007; Christoffoleti et al., 2007; Cavenaghi et al., 2007; Guimarães et al., 2008; Tavares et al., 2010; Cardoso et al., 2013; Costa et al., 2014). From an environmental perspective Otto et al. (2016) reviewed recent developments in N management for sugarcane-biofuel production and verified that, the transformation of nitrogen (N) fertilizers into N_2O gases can give the same advantages and could replace fossil fuels with biofuels. However, maintaining straw over soil surface and crop rotation with N-fixing legume can potentialy reduce the N requirements of sugarcane crop which is very important for sustainable biofuel production.

Factors like emergence, bud sprout and plant growth are also influenced by changes in the crop environment (Franchini et al.,

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2012). It is also important to mention that the sugarcane varieties available today were developed at a time when burned cane harvesting system was in practice, and many of them respond differently to the mechanical harvest system (Souza et al., 2005).

Campos (2010) evaluated the tillers, fresh biomass accumulation and productivity of ratoon sugarcane (var. RB855453) under straw management in Oxisol and reported that keeping sugarcane straw over the entire field showed negative effect on ratoon development which led to low tiller biomass and productivity. However, Ball Coelho et al. (1993) observed that leaving the straw on soil surface (oxic Argisol) caused 43% increase in dry matter production of the first sugarcane ratoon. Oliveira et al. (1995) and Resende et al. (2006) also reported that keeping straw over the soil surface has beneficial effect, however, it was not mentioned that how much straw is needed to achieve such effects and that what is the effect of small straw quantity.

Calculating the amount of straw needed as soil cover for the development of sustainable and optimized sugarcane production enables the surplus to be used for electricity or second generation ethanol production, which can 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, keeping in mind that one ton of straw can produce 270 liters of ethanol, and one ton of sugarcane can produce 80 liters of ethanol (Santos et al., 2012). Marin et al. (2016) reported that in order to meet the demands of the country by 2024, Brazil which is the world highest producer of sugar and ethanol, has to expand its area by 45% and that studies aimed at increasing productivity are urgent and necessary.

This study aimed to evaluate the effect of different amounts of straw mulching on the development and productivity of sugarcane during the first and second ratoons.

2. Material and methods

The experiment was conducted in an area that belong to the Bandeirantes Sugar and Alcohol Plant, located in the city of Bandeirantes, latitude 23° 06'S, longitude 50° 21' W and altitude of 440 m. Based on the Koeppen climatic classification, the climate of the region is Cfa, with an average annual rainfall of 1.300 mm. The average annual insolation is 7.14 h^{-1} day.

The area where the experiment was conducted has been cultivated with sugarcane for the last 65 years. During this period, manual method of harvesting (burned cane harvesting system) was used until 2010, when it was replaced by the mechanical harvesting system.

The experiment was carried out using randomized block design with four replications, during the first and second ratoon cycles of sugarcane (*Saccharum* spp. variety SP 801816). The climatological water balance (Fig. 1) during the trial implementation period, was calculated using Thornthwaite and Mather (1955) method. Data of average monthly temperature and total monthly rainfall were provided by the meteorological station of the Agronomic Institute of Paraná (IAPAR), located in Bandeirantes city, two kilometers from the experimental site. The value of available water capacity (AWC) considered was 100 mm.

The soil is classified as Oxisol (Embrapa, 2013), with a texture 61% of clay; 2% silt and 37% sand, calculated using particle size analysis. The soil was chemically analyzed and a layer of 0–0.2 m depth showed the following results: Organic matter (g kg^{-1}) 34.2; P (mg dm^{-3}– extractor Melich) 39.9; K (Cmolc dm^{-3}) 3.0; Ca (Cmolc dm^{-3}) 7.8; Mg (Cmolc dm^{-3}) 1.8; H + Al (Cmolc dm^{-3}) 3.0; CEC (Cmolc dm^{-3}) 15.7; pH ($CaCl_2$) 5.6 and V (%) 80.8.

Before the plantation, 70 Mg ha^{-1} of filter cake was applied to the field area as a common practice. Similarly, 150 m^3 of vinasse was also applied for the last crop to supply the potassium extracted by the previous crop (Barbosa et al., 2013). The bulk density (g cm^3) of different layers analyzed at the same period of time is as follows: 0–0.10 m depth: 1.33; 0.10 to 0.60 m: 1.30, indicating no physical obstacle to the development of the roots. The land was prepared for cultivation using a disk harrow and light harrowing.

Each plot consisted of 10 sugarcane lines with a length of 10 m each (10 lines × 10 m), totaling 100 linear m with spacing of 1.50 m between the lines. For data collection, six central rows were used with nine linear meters, totaling 54 linear meters. Treatments which were evaluated during the experiments are as follows: burned sugarcane (where 100% of straw was burned), 0%, 25% (5 Mg ha^{-1}), 50% (10 Mg ha^{-1}), 75% (15 Mg ha^{-1}) and 100% (20 Mg ha^{-1}) of sugarcane straw left on the soil surface (mulching).

For evaluation purpose, stems of at least 2 m length were collected at 60, 120, 180, 240 and 370 days after harvest (DAH) for the first ratoon and at 60, 120, 180, 240 and 270 DAH for the second ratoon. The following variables were evaluated at each sampling: number of green leaves, leaf area (LA), leaf area index (LAI), number, length (m), diameter (cm) and production of stems (Mg ha^{-1}).

The average number of green leaves per tiller were determined by counting the fully expanded leaves, with a minimum 20% of green area, from the leaf +1 (Hermann and Câmara, 1999). The leaf area (LA) was calculated with the help of a leaf area meter LiCor model LI 3100, by collecting the TVD leaf ("top visible dewlap") of each existing tiller, both in the 2 linear m and posteriorly, using Nassif et al. (2013) methodolgy. The leaf area per tiller was calculated using the equation $LAT = LA \times (N + 2)$, where: LA is the leaf area; N is the number of open green leaves and 2 is the weighting factor for leaves that are not yet fully expanded. The leaf area index (LAI), evaluated only on the first ratoon, was calculated using the equation: $LAI = NTI \times LA/A$, where: NTI is the number of tillers (m^2); LA is the leaf area per tiller (m^2); and A is the the land area in m^2 used for the evaluation.

Stems in the two linear meters of each plot were counted for obtaining the number of stems per hectare. Average stem length was calculated by measuring each stem from ground level to the first visible atrium, classified as leaf +1. The stem diameter was measured in the middle third of the stems. Productivity was calculated from the stem weight of each evaluation period. The leaves and tips of all the stems were removed prior to weighing.

The experiment was installed in August 2010, and immediately after plantation, each straw treatment was applied to the soil. The emergence of the first ratoon occurred in September 2011 which was than harvested in December 2012. The harvest of the second ratoon occurred in October 2013. Thus, the data obtained in the first and second ratoons of sugarcane is a result of two and three years of cultivation under straw cover, respectively.

The data was analyzed using analysis of variance (ANOVA) and the means were compared via Tukey's test ($P < 0.05$) using the SISVAR software 5.0 (Ferreira, 2011).

3. Results

A significant effect of straw mulching was observed on the LAI in the first ratoon, at 120 and 370 DAH (Fig. 2). In this cycle, where there was a severe water stress (Fig. 1), treatments 25% (5 Mg ha^{-1}) and 75% (10 Mg ha^{-1}) straw mulching resulted in higher LAI at 120 DAH (6.7 and 6.8, respectively), that significantly differed from burned cane (5.3). A sharp decline was observed at 240 DAH, while at the end of the cycle (370 DAH) 50% of straw mulching resulted in the highest average (4.1), significantly higher than any other treatments, except for the 100% straw treatment (?). The burned cane presented the lowest mean value (1.9).