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Filter cake in industrial quality and in the physiological and acid phosphatase activities in cane-plant

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ABSTRACT

Sugarcane filter cake, a phosphorus-rich (P) fertilizer, can affect not only P storage in sugarcane (*Saccharum officinarum* L.), but also its metabolism and photosynthesis. In this study, was evaluated the effect of different mineral fertilizers, with and without the use of filter cake, on P levels, gas exchange, acid phosphatase activity, sugar, hydrated alcohol production, and total soluble solids. Sugarcane (variety RB86 7515) was cultivated on dystrophic Typic Haplustox in a randomized complete block design. Three replicates were established in a 3 × 4 × 2 factorial scheme, with three P sources (Triple Superphosphate-TS, Natural Reactive Bayovar Phosphate-BP, and Natural Araxa Phosphate-AP), four rates of P as P_2O_5 (0, 90, 180, and 360 kg ha^{-1}), and the presence or absence of filter cake (7.5 Mg ha^{-1}, dry weight). The levels of foliar P (PCL) were determined, along with the accumulation of P in aerial plant parts (AAP), net CO_2 assimilation (A), stomatal conductance (g_s), transpiration rate (E), acid phosphatase activity (APL), hydrated alcohol, total soluble solids (TSS), total recoverable sugar (TRS), and stalk production. The highest P rate with filter cake yielded the maximum concentration of P in leaves (1.7 g kg^{-1}), leading to the highest P accumulation in aerial plant parts (17.8 kg ha^{-1}), and furthering a sugar production of 197.1 kg t^{-1}, and stalk production (122.6 Mg ha^{-1}). The highest rate of Triple Superphosphate alone or with filter cake yielded the lowest acid phosphatase activity, the highest rate increased the accumulation of P in aerial parts (18.8 kg ha^{-1}), and for stalk production, produced 123.1 Mg ha^{-1} of stalks. The use of Triple Superphosphate associated with filter cake increased the production of sugar (192.5 kg t^{-1}), hydrated alcohol (91.3 L t^{-1}) and total soluble solids (18.4°Brix), while the use of higher P rates, regardless of the source, increased gaseous exchange in sugarcane plants.

1. Introduction

Sugarcane productivity in tropical regions is commonly related to the availability of phosphorus (P), which is a limiting nutrient in these regions. Adequate P levels are essential for photosynthesis and stomatal conductance (Jacob and Lawlor, 1991; Reich et al., 2009). Plants that are P deficient usually have reduced photosynthetic capacity, which is reflected in a low intercellular CO_2 concentration, resulting in decreased stomatal conductance (Aspelmeier and Leuschner, 2004). When stomatal conductance is impaired, the water vapor flux to the atmosphere is reduced, leading to decreased transpiration rates (Gonçalves et al., 2010).

Phosphorus also plays an important role in stimulating root growth (Zhang and Barber, 1992), as it increases the area of root exploration in the soil, thus increasing water absorption and the turgor of guard cells (Kuwahara and Souza, 2009).

As soil has a high capacity for P absorption, usually apply large amounts of high-phosphate fertilizers, which is also a common in many scientific studies (Santos et al., 2009; Caione et al., 2011; Simões Neto et al., 2012). The filter cake, a byproduct of sugar and ethanol production that is generated in large volumes from ground sugarcane, is rich in organic matter and several nutrients, especially P. It can also improve the efficiency of P fertilization when mineral phosphate fertilizers are used as the liberated organic acids compete for the same adsorption sites, decreasing P adsorption to colloids in the clay fraction of soil (Pavinato and Rosolem, 2008). Therefore, filter cake can

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complement the use of mineral fertilization.

Phosphorus levels may influence several biochemical processes, including acid phosphatase activity (E.C.3.1.3.2) (Besford, 1979; Tanksley, 1983; Kuwahara and Souza, 2009). The activity of the enzyme is increased when the plant is deficient in P (Silva and Basso, 1993; Bovi et al., 1998) and could therefore be used to diagnose low P levels. However, using acid phosphatase activity as a biochemical indicator of P nutritional status in sugarcane has not been well studied. Nevertheless, the enzyme may be employed in future studies as a molecular marker for plants that are efficient in reabsorbing compartmentalized P, especially in plants cultivated on soils with deficient levels of P, and it can also be used as a tool for genetic improvement programs. Acid phosphatase activity, along with the other processes in sugarcane that respond to P deficiency, as discussed above, are all good indicators of the effects of P deficiency on plant metabolism and photosynthesis.

Several studies highlight the effects of filter cake application on P levels in sugarcane, in particular, studies have examined specific physiological and nutritional aspects in order to improve the nutritional efficiencies of the crop (Vasconcelos, 2013; Santos et al., 2014; Caione et al., 2015). An adequate supply of P increases both the productivity and quality of sugarcane crops (Korndörfer, 1994; Korndörfer and Melo, 2009; Santos et al., 2010). Thus, the aim of the present study was to evaluate the effect of phosphate fertilizers and filter cake on the physiology, acid phosphatase activity, production, and industrial characteristics of the cane-plant.

2. Materials and methods

2.1. Experimental site, climate, and soil

The experiment was carried out from June 2011 to June 2012 in the Fazenda Santo Antônio, Itajobi, São Paulo State, Brazil (−21°11′ S and −49°1′ W), at an elevation of 469 m. This region typically has a rainy summer and dry winter, with an average annual temperature of 23.2 °C and average annual precipitation of 1328 mm (CEPAGRI, 2015). In this study, was used the sugarcane variety RB86 7515, which has a high growth rate and stature, growth erect, with high stalk density and sucrose content, and has good agricultural productivity (PMGCA, 2008). Meteorological data were obtained from a nearby weather station located in the city of Catanduva-SP (Fig. 1). Throughout the experiment, was verified a period of surplus precipitation followed by an interval of drought.

The soil of the experimental area is dystrophic Red-Yellow Latosol (EMBRAPA, 2013), which corresponds to the dystrophic Typic Haplustox (USDA, 1999). Twenty composite soil samples (equivalent to 12 simple samples) for the total area were collected, and the results were homogeneous for the entire area.

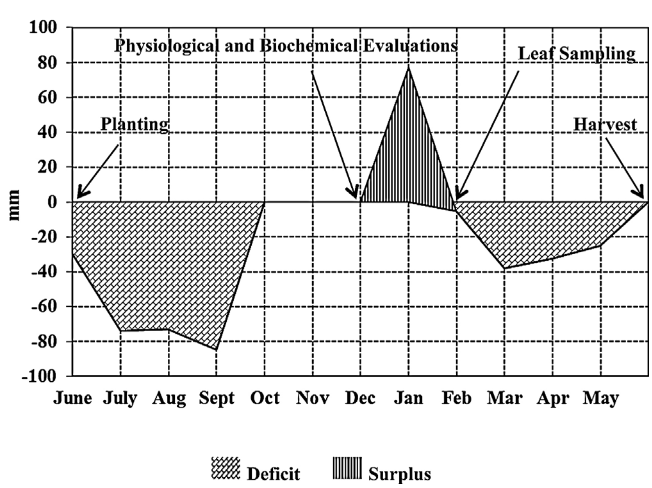

Fig. 1. Water balance from Catanduva, São Paulo State, from June 2011 to June 2012.

Table 1
Chemical and granulometric analysis of soil in the experimental area, Fazenda Santo Antonio, Itajobi, SP, Brazil.

Depth (m)	pH	S.O.M[a]	P	K	Ca	Mg	H + Al	CEC[b]	T[c]	V[d]
	$CaCl_2$	g dm^{-3}	mg dm^{-3}	mmolc dm^{-3}						%
0.00–0.20	6.1	10.0	5.0	1.1	29.0	13.0	10.0	42.3	52.3	81
0.20–0.40	5.6	10.0	4.0	0.9	25.0	9.0	12.0	34.8	46.8	74

Depth (m)	Granulometry			
	Clay	Silt	Fine Sand g kg^{-1}	Coarse Sand
0.00–0.20	209	40	464	287

S.O.M[a]: soil organic matter.
CEC[b]: cation exchange capacity.
T[c]: CEC + (H + Al).
V[d]: base saturation.

Both the chemical and particle size analysis of the soil were performed based on the methods of Raij et al. (2001) and Camargo et al. (2009) (Table 1).

2.2. Treatments and crop cultivation

The treatments were defined by different P rates, using 180 kg ha^{-1} of P_2O_5 as the reference rate, which is standard for São Paulo State (Spironello et al., 1997). The experimental design was a randomized complete block design with three replications in a 3 × 4 × 2 factorial scheme. The factors were: three sources of P [Triple Superphosphate (TS; 41% P_2O_5 in citric acid); Natural Reactive Bayovar Phosphate (BP; 14% P_2O_5 in citric acid); and Natural Araxa Phosphate (AP; 4% P_2O_5 in citric acid)]; four P rates (0, 90, 180, and 360 kg ha^{-1}); and presence or absence of filter cake (7.5 Mg ha^{-1} dry matter).

Basic fertilization and coverage were performed following Spironello et al. (1997), by applying 151 kg ha^{-1} of $(NH_4)_2SO_4$, 204 kg ha^{-1} of KCl, and 25 kg ha^{-1} of $ZnSO_4$ and 30 kg ha^{-1} of CH_4N_2O and 160 kg ha^{-1} of KCl respectively. Each plot measured 112.5 m^2 and included five 15 m rows spaced at intervals of 1.5 m, only the three central rows were used (useful area of 67.5 m^2) for the experiment.

The chemical analysis of filter cake was performed based on Alcarde (2009) and the following values were obtained: N (total) 3.4 g kg^{-1}; P_2O_5 (total) 8.2 g kg^{-1}; P_2O_5 (2% citric acid soluble) 7.8 g kg^{-1}; K_2O 2.2 g kg^{-1}; and CaO 12.2 g kg^{-1}. After the filtration process, the filter cake was deposited outside and left to rest for a few days in order to lower the temperature between 60 and 40 °C, when inoculates the microorganisms on the pile. A two-month composting is then performed, with periodic turnings, after this stage, when the compost is mature and cooled then can be used in crops.

All produced filter cake is used during the harvest, its reduces the need fertilizers, furthermore, the milling period extends for almost a year, the production of filter cake occurs continuously so there is no need to stock the product. For sugarcane, the filter cake is applied within the planting furrow or across the total area. In subsequent years (ratoons), it is applied annually in between planting lines.

The filter cake used in this study contained 304.7 g kg^{-1} organic matter (Walkley and Black, 1934), was added 800 mL of BioPack[sc] (which contains organic acids and P-solubilizing microorganisms), with the goal of composting eight tons of filter cake, at a dosage of 100 mL per ton of filter cake, the mixture was composted for eight weeks.