INFLUENCE OF *Brachiaria brizantha* IN PHYSIOLOGICAL CHARACTERISTICS RELATED TO PHOTOSYNTHESIS AND EFFICIENT USE OF WATER IN SUGARCANE[1]

*Influência de **Brachiaria brizantha** nas Características Fisiológicas Relacionadas a Fotossíntese e Uso Eficiente da Água em Cana-de-Açúcar*

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ABSTRACT - The increase in density of weeds increases also its competitive ability, which affects the physiological aspects of crops. This study aimed to evaluate the interference of increasing densities of *Brachiaria brizantha* over sugarcane varieties RB72454, RB867515 and SP80-1816 based on physiological variables related to the photosynthesis rate. For this, a field was installed, being treatments composed by 12 densities of the competitor, ranging from 0 to 112 plants m^{-2}, emerged simultaneously to the crop. At 120 days after crop emergence the substomatal CO_2 concentration (Ci – µmol mol^{-1}), photosynthetic activity (A – µmol m^{-2} s^{-1}), stomatal conductance (gs – mol m^{-1} s^{-1}), the transpiration rate (E), the water use efficiency (WUE) and the shoot dry mass (SDM – g per plant) of the crop were evaluated. All physiological variables and SDM of the variety RB72454 were affected by increasing the density of *B. brizantha*, as well as the transpiration rate of the variety RB867515. The variety RB72454 showed lower competitive ability with weeds and its photosynthetic ability is limited by factors that reduce the influx of CO_2 into the leaf.

Keywords: weeds, *Saccharum* spp., photosynthesis, transpiration, competition.

*RESUMO - O aumento da população das plantas daninhas eleva a habilidade competitiva dessas com as plantas cultivadas, podendo causar interferência nos aspectos fisiológicos das culturas. Objetivou-se com o trabalho avaliar a interferência de populações de **Brachiaria brizantha** nas características relacionadas a atividade fotossintética e o uso eficiente da água das cultivares de cana-de-açúcar RB72454, RB867515 e SP80-1816. Foi conduzido um experimento a campo, onde os tratamentos foram constituídos por 12 populações de plantas de **B. brizantha** que emergiram juntamente com a cultura. Aos 120 dias após a emergência da cana-de-açúcar foram realizadas as avaliações da concentração de CO_2 subestomático (Ci – µmol mol^{-1}), a atividade fotossintética (A – µmol m^{-2} s^{-1}), a condutância estomática (Gs – mol m^{-1} s^{-1}), a taxa de transpiração (E), a eficiência do uso da água (EUA) e a massa seca da parte aérea (SDM – g por planta) da cultura. Todas as variáveis fisiológicas e a massa seca da cultivar RB72454 foram afetadas pelo aumento da densidade das plantas de **B. brizantha**, bem como a transpiração da cultivar RB867515. A cultivar RB72454 apresenta menor habilidade competitiva com as plantas daninhas e a atividade fotossintética é limitada por fatores que reduzem o influxo de CO_2 para o interior da folha.*

Palavras-chave: plantas daninhas, *Saccharum* spp., fotossíntese, transpiração, competição.

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INTRODUCTION

The competition between crops and weeds is the major biotic factor limiting the yield of crops like sugarcane (*Saccharum* spp.), and may in some cases cause yield losses of around 40% (Kuva et al., 2003). Several weed species are found in sugarcane plantations, and among those species, the genus *Brachiaria* is highlighted due to its potential of causing interference (Vidal et al., 2004). This genus belongs to the same family of the crop, thus demanding similar levels environmental resources (Radosevich et al., 1997).

The competitive ability of weeds in capture of environmental resources vary depending on the species present at the area, the population density and the timing of weed emergence in relation to the emergence of the crop (Vidal et al., 2004), as well as the competitive ability native to the crop variety (Galon et al., 2010). The competition between weeds and crops leads to a lower supply of resources for some species – the less efficient in capturing that given resource, causing deficiencies that culminate in changes at physiological parameters related to photosynthesis. The water deficit (Floss, 2008), nutrition status (Melo et al., 2009) and low quality or quantity of light (Sharkey & Raschke, 1981) are usually the main ones. These limitations can lead to an unbalancing in processes like stomatal conductance and internal concentration of gases, and hence the photosynthetic activity and also the efficient use of water will be affected.

Among the resources prone to competition by plant species, water is considered as one of the most limiting for high yields, especially in warm periods with low rainfall. In these cases an important feature of plants can determine its success - the Water Use Efficiency (WUE). This is characterized as the amount of dry mass produced in relation to a given amount of water spent in producing that amount of dry mass (Silva et al., 2007). A higher WUE is a feature that may be intrinsic to the plant, hence the choice of varieties with native higher WUE may be the best choice to minimize losses in crop yield due to weed competition by water (Baptista et al., 2001). Plants of the genus *Brachiaria* stand out among the major weeds that compete with sugarcane (Vidal et al., 2004), and also present high WUE due to its C_4 carbon route metabolism (Gurevitch et al., 2009).

The most efficient use of water is directly related to the dynamics of stomatal opening, because as the plant absorbs CO_2, water is lost through transpiration, with varying intensity depending on the gradient of potential between the sub-stomatal leaf chamber and the atmosphere around it (Concenço et al., 2009). It is estimated that for every 3,70 g m^{-2} of dry mass accumulated by *Brachiaria decumbens* there is an yield loss of around 1 t ha^{-1} for sugarcane (Kuva et al., 2003). The potential of impacting crops is increased because thisspecies is a forage, and when farmers plant sugarcane in areas where cattle raising was previously present, the rich soil seed bank of this species will keep infesting the crop for a long time, and thus proper attention should be paid in controlling this weed species among at sugarcane crop.

Whereas the competition with weeds cause physiological changes in crops, it is assumed that the physiological characteristics related to photosynthesis and water use efficiency can be indicators of the level of competition between these species and crops (Concenço et al., 2009; Galon et al., 2010). Therefore, this study aimed to evaluate the interference of populations of *Brachiaria brizantha* in traits related to photosynthetic activity and water use efficiency of sugarcane varieties RB72454, RB867515 and SP80-1816.

MATERIAL AND METHODS

The experiment was conducted at the Experimental Station belonging to the Universidade Federal de Viçosa (UFV), Viçosa-MG, Brazil. Soil chemical and physical characteristics are presented at Table 1. Sugarcane was planted at the typical season for one-year-old sugarcane harvest, being the soil tillage accomplished by plowing and harrowing with posterior marking of the planting rows spaced in 1,4m.

Planting density was 18 buds m^{-1} in the row, and fertilization was applied at planting, according to results of soil analysis (Table 1)

Table 1 - Physical and chemical soil sampling, depth from 0 to 10 cm, at New Garden, University of Viçosa Experimental Station, Viçosa-MG, Brazil, 2008

Chemical analysis[1/]												
pH	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	CTC(t)	CTC (T)	V	m	MO
(H_2O)	(mg dm^{-3})		($cmol_c$ dm^{-3})							(%)		(dag kg^{-1})
6.0	7.4	168	4.2	0.7	0.0	4.46	5.33	5.33	9.79	54	0	2.4

Physical analysis[1/]				
Clay	Silth	Thick sand	Thin sand	Texture class
%				
47	32	7	14	Clay

1/ Analyzed by the Soil Laboratory, Federal University of Viçosa, Brazil. PH in water, relation 1-2,5; P-K Extracted by Mehlich 1. Ca-Mg and Al extrator KCl – 1 mol L^{-1}; H + Al extractor calcium acetate 0,5 mol L^{-1} – pH 7,0. SB: sum of exchangeable bases. CTC (t): Effective Cation Exchange Capacity. CTC (T): Cation Exchange Capacity at pH 7,0. v: base saturation. m: aluminum saturation. MO: organic matter = C.org x 1,724 – Walkley-Black.

and recommendations for for the crop: 500 kg ha^{-1} of NPK formulation 8-28-16, plus top dressing with application of 160 kg ha^{-1} of potassium chloride.

The experimental unit consisted of six rows (8.4 m) with 5.0 m length, with a total area of 42 m^2. Treatments consisted of 12 densities of *Brachiaria brizantha*, and three varieties of sugarcane. Densities of *B. brizantha* were: 0, 1, 3, 7, 15, 32, 40, 32, 64, 92, 88, 112; 0, 1, 4, 14, 10, 18, 28, 30, 36, 54, 62, 72; and 0, 1, 3, 6, 14, 20, 24, 26, 26, 32, 46, 56 plants m^{-2} for varieties RB72454, RB867515 and SP801816, respectively.

B. brizantha was seeded in all plots 10 days before the emergence of sugarcane at a density of 10 kg ha^{-1} of seeds, and when plants were at the stage of 2 leaves to 1 tiller populations were established by application of the herbicide MSMA (2 L ha^{-1} of Volcano®). In order to establish the desired populations of *B. brizantha* the number of seedlings at each plot desired to establish the expected density was protected with plastic cups prior to herbicide application; hence these seedlings were not harmed by the herbicide. The remainder of the weed species was controlled with application of 2,4-D or by roughing. Herbicides were applied using a backpack sprayer propelled by CO_2, attached to an application bar equipped with four spray nozzles 110.02 TT model, calibrated to apply 150 L ha^{-1}.

At 120 days after emergence of the crop and *Brachiaria* plants, evaluations were carried out in the middle third of the youngest fully expanded leaf of the sugarcane by using an infrared gas analyzer (IRGA), ADC, model LCA PRO (Analytical Development Co. Ltd, Hoddesdon, UK). At this evaluation sub-stomatal CO_2 concentration (Ci – μmol mol^{-1}), photosynthetic activity (A – μmol m^{-2} s^{-1}), stomatal conductance (GS – mol m^{-1} s^{-1}), and transpiration rate (E – mol H_2O m^{-2} s^{-1}) were determined, and the water use efficiency (WUE – mol CO_2 mol H_2O^{-1}) was calculated by the relation between CO_2 fixed by photosynthesis and the amount of transpirated water at the same interval. These evaluations were conducted between 7:30 and 9:30 a.m., one block per day, using natural sunlight in order to keep homogeneous environmental conditions when judging treatment effects at the analysis of variance. The shoot dry mass (SDM – g per plant) of the crop was also determined by collecting all plants in a sampled area of 1m in the row. Plants were cut at soil level, placed in paper bags and dried in oven at 60°C until constant weight.

Data were tested for homoscedasticity and then submitted to analysis of variance. Subsequent analysis of linear and nonlinear regressions were performed to evaluate the effects of populations of *B. brizantha* on physiological characteristics of each variety of sugarcane, using the means of each treatment. The regression model was selected based on statistical significance (F test), the adjusted coefficient of determination (R^2) and the biological significance of the model.

RESULTS AND DISCUSSION

The SDM of sugarcane plants of the variety RB72454 decreased as the population of *B. brizantha* increased. For the other two varieties there was no change as a function of the competition with *B. brizantha* (Figure 1). This impact was also observed for the photosynthetic activity, which may have led to reduced production of assimilates and deposition of dry matter. Increasing the density of weeds inside crops caused lower SDM accumulation in several crops, such as rice (Concenço et al. 2009; Galon et al., 2010), soybean (Kuva et al., 2003) and maize (Vidal et al., 2004). However, some varieties show distinct competitive ability against weeds (Concenço et al., 2009; Galon et al., 2010), being less affected by the competition.

The sub-stomatal CO_2 concentration (Ci) of the variety RB72454 was reduced as the density of *B. brizantha* was increased (Figure 2). The Ci is a physiological variable influenced by several environmental factors, like water and light availability (Floss, 2008) and it changes according to the variations of the stomatal conductance (which may limit the entrance of CO_2 in the leaf) or to the photosynthetic activity (which may incorporate the CO_2 present at the sub-stomatal chamber). The Ci was distinct among sugarcane varieties, being higher for the variety RB72454 in comparison to the others (Galon et al., 2010).

The changes in the values of Gs (Figure 3) was similar among varieties. Hence, the higher Ci observed for the variety RB72454 may be attributed to a possible lower photosynthetic activity which did not incorporate the CO_2 available at the sub-stomatal leaf chamber. Concenço et al. (2009) observed that the difference at Ci between rice varieties was most probably attributed to the distinct photosynthesis rate among varieties.

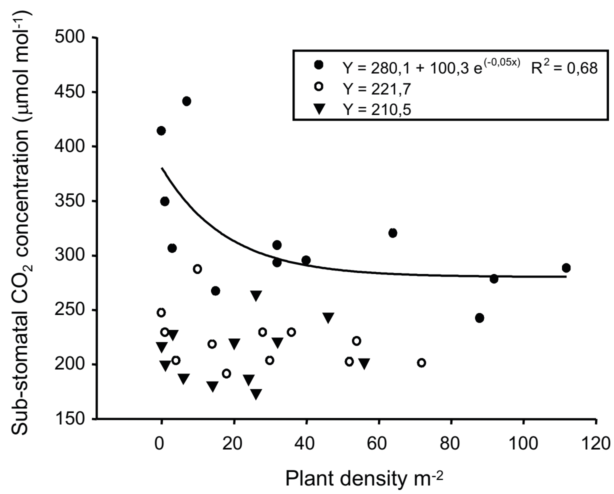

Figure 2 - Sub-stomatal CO_2 concentration (µmol mol^{-1}) in leaves of sugarcane varieties (•) RB72454, (o) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

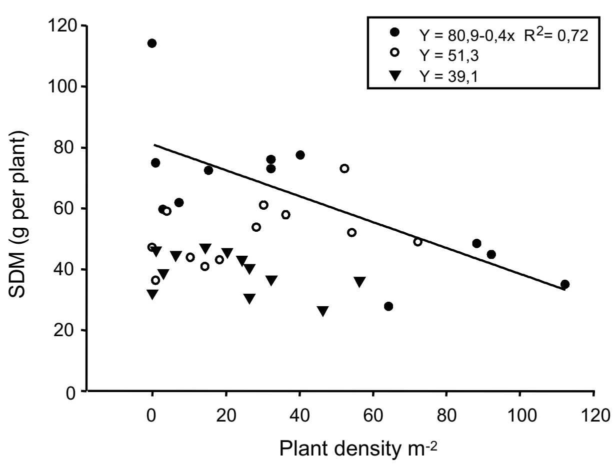

Figure 1 - Shoot dry mass – SDM (g per plant) of sugarcane varieties (•) RB72454, (o) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

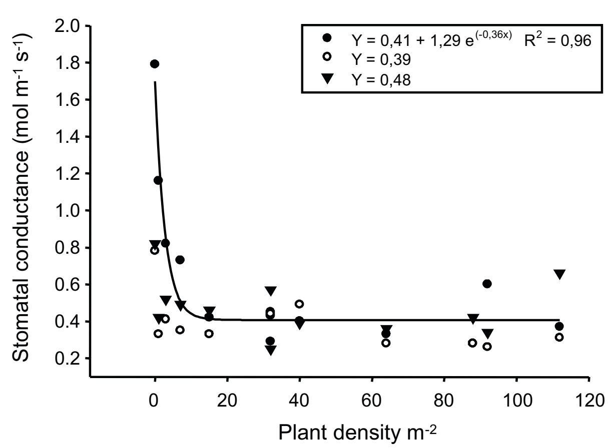

Figure 3 - Stomatal conductance – GS (mol m^{-2} s^{-1}) at leaves of sugarcane varieties (•) RB72454, (o) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

A reduction in stomatal conductance (Gs) was observed for the variety RB72454 as the density of *B. brizantha* was increased up to 16 plants m^{-2}, while the other two varieties were not affected (Figure 3). Corroborating with these results, there were no differences on the values of Gs among sugarcane varieties at a study conducted by Galon et al. (2010) under field conditions. Differential responses of reduced GS in plants subjected to competition were observed for the rice crop, where one variety presented lower Gs in relation to the others evaluated at the same trial (Concenço et al., 2009). The GS is dependent on several factors, such as the number, size and diameter of stomatal opening, features dependent on endogenous and environmental factors (Brodribb & Holbrook, 2003). It is also highlighted that the variation at Gs as a function of increasing at density of the competitor may be directly related to the lower water supply, because as the density of *B. brizantha* was increased, there was also an increasing at the amount of water extracted from soil by the plant community, thus reducing its availability. With less water available at the soil, the plant tends to control more tightly the stomatal opening avoiding losing water to the environment (Taiz & Zeiger, 2009).

The transpiration rate (E) of the varieties RB72454 and RB867515 were reduced as the density of *B. brizantha* was increased. For the former, this reduction was observed until 40 plants m^{-2} of *B. brizantha*, becoming constant at higher densities (Figure 4). The reduction of E is directly related to water availability for plants (Floss, 2008), thereby, it is hypothesized that as the density of *B. brizantha* was increased, there was a proportional increasing in competition for water between the plants of the crop and the competitor. Some weed species present superior ability to extract water from soil than most crop plants, usually adapted to ideal conditions of cultivation. For example, it was observed that the weed species *Bidens pilosa* is capable of extracting water from soil at tensions three times higher than those in which soybean and bean plants are capable of extracting water (Silva et al., 2007), illustrating the greater ability of some weeds in surviving under low water availability.

There was a reduction in photosynthetic rate (A) for the variety RB72454 as the density of the competitor was increased, while the other varieties were not affected (Figure 5). IN this case, the photosynthetic rate is being limited by the lower availability of CO_2 into the sub-stomatal chamber of the leaf due to a reduced influx of CO_2, as noted at the evaluations of Ci and Gs. However, some plants are more efficient than others at the optimization of stomatal opening and closure, in a way they are able to manage through small reductions in water availability by

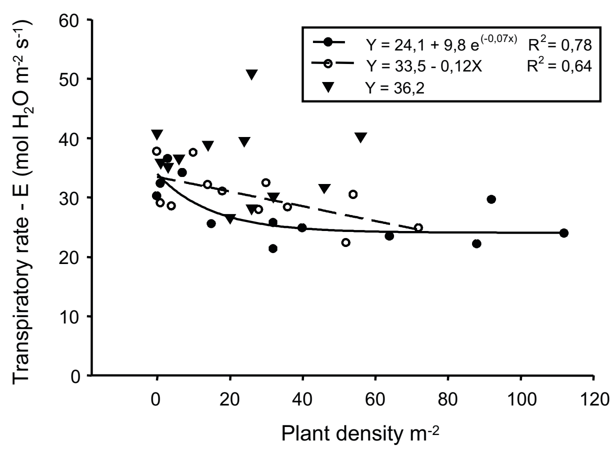

Figure 4 - Transpiratory rate – E (mol H_2O m^{-2} s^{-1}) in leaves of sugarcane varieties (●) RB72454, (○) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

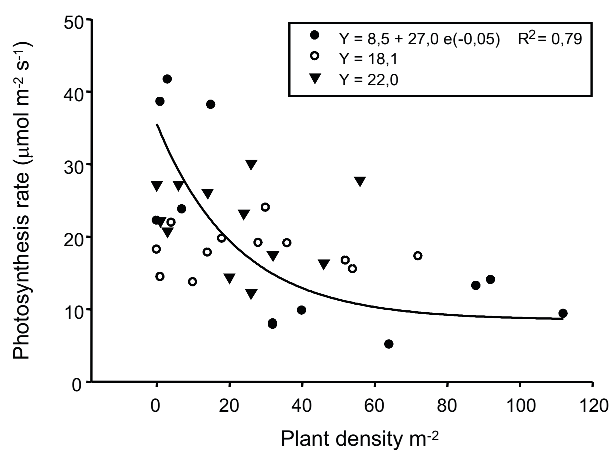

Figure 5 - Photosynthesis rate – A (µmol m^{-2} s^{-1}) of sugarcane varieties (●) RB72454, (○) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

balancing gas and water fluxes in and out of the leaves, keeping adequate photosynthetic rate under these conditions (Floss, 2008). Other factors like nutritional deficiency can also lead to a disability in controlling properly the stomatal opening. For example, proteins, enzymes or nutrients such as potassium, are directly related to the adjustment of the stomatal opening, and its deficiency may limit the photosynthetic activity (Melo et al., 2009).

The water use efficiency (WUE) represents the amount of CO_2 fixed by photosynthesis in a given period of time in relation to the amount of water spent at the same period. In this way, plants which are able to achieve high photosynthetic rate while losing less water are considered as more efficient in the use of this resource (Floss, 2008). There was a reduction at the WUE for the variety RB72454 as the density of *B. brizantha* was increased, being the higher interference observed at lower densities of the competitor (Figure 6), showing that this sugarcane variety is more affected by the competition in comparison to the other two varieties tested. The varieties RB867515 and SP80-1816 presented a proportional reduction at E and A, while keeping the WUE unchanged. Some researchers have observed differences between varieties in rice (Concenço et al., 2009) and sugarcane (Galon et al., 2010) crops when these varieties are submitted to either intra- or inter- specific competition.

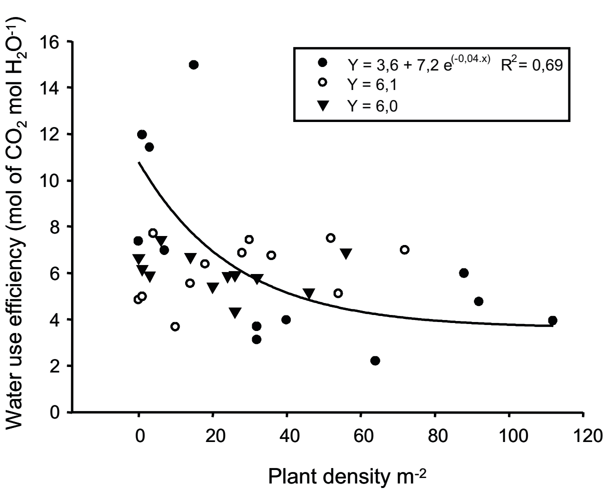

Figure 6 - Water use efficiency - WUE (mol CO_2 mol H_2O^{-1}) of sugarcane varieties (•) RB72454, (○) RB857515 and (▼) SP8018-16 under competition with increasing densities of *Brachiaria brizantha*. DFT/UFV, Viçosa-MG, 2008/09.

Based on the results, it is possible to conclude that the variety RB72454 was the most affected by the competition with *B. brizantha*, both for light and water. Both the photosynthetic activity and the water use efficiency of sugarcane plants are affected as the density of the competitor is increased, due to factors that lead to lower CO_2 influx into leaves and increased transpiration. Sugarcane varieties tested present differential susceptibility to the competition with *B. brizantha*, being RB72454 the most affected and thus demanding more accurate techniques of weed control to guarantee high yields.

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