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Physiological aspects of acacia and eucalyptus in competition with Brachiaria

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Abstract

Competition between plants results in the reduced availability of certain resources essential for the species, leading to deficiencies that culminate in changes in their physiological characteristics. In the intercropping systems the species in the study grew under competitive conditions. The competitive potential of plants for environmental resources was dependent upon the other species present in the area, as well as the competitive characteristics of the individuals concerned. Therefore, this study was conducted to evaluate the physiological characteristics of *Acacia mangium* and *Eucalyptus urophylla* × *grandis* in the early stages of development when grown intercropped with forages of the genus *Brachiaria*. An experiment was set up using a randomized complete block design, in which the treatments consisted of a factorial arrangement of 2 × 4, being respectively, two tree species (acacia and eucalyptus) and the forage species, *Brachiaria brizantha* cv. Marandu and cv. Piatã, *Brachiaria decumbens* cv. Basilisk grown together with the tree species, plus two additional controls with acacia and eucalyptus grown in monocrop. The coexistence of the forages negatively affects the photosynthetic characteristics of both the tree species. *B. decumbens* was the species that promoted a negative effect on most of the variables in both acacia as in eucalyptus, presenting a greater competitive capacity among the brachiaria studied.

Keywords: *Acacia mangium*, *Brachiaria* spp., *Eucalyptus uroplylla* x *grandis*, intercropping systems.
Abbreviations: Δ_C_CO_2 consumption; C_i_internal carbon; G_s_stomatal conductance of water vapor; *E*_transpiration rate; *A*_photosynthetic rate; Δ_T_leaf temperature; WUE_water use efficiency.

Introduction

In recent decades, the use of the agroforestry systems as an alternative method for the recovery of degraded areas has been widespread, where tree species are grown along with agricultural crops and, or forages, which in this case can promote improvement in the physicochemical properties of the degraded soils, also considering improvement in the activity of the microorganisms (Reinert, 1998; Mendonça et al., 2001). These systems which, however, do not restore important aspects of the forest communities, such as structure and biodiversity, can, if well planned, environmentally approach these communities recovering essential functions for sustainability such as nutrient cycling; carbon retention, the accumulation of which contributes to a reduction in greenhouse gases; as well as providing thermal comfort to the grazing animals and consecutively higher livestock indices (Leme et al., 2005; Pires et al., 2007).

In intercropping systems, the plant species of interest find themselves in a condition of intra-and interspecific competition for resources. The competition potential of the plants varies depending upon the other species found in the area (Rigoli et al., 2008), the level and population density (Vidal et al., 2004), and the time of emergence compared with the emergence of the crop (Smith et al., 2009), as well as by competitive characteristics of the genotypes involved (Galon et al., 2007). The competition by the brachiaria plants with the agricultural crops and, or, forestry systems leads to a lower supply of certain resources for these crops, causing deficiencies that culminate in changes in the physiologic parameters related to photosynthesis, such as water stress (Floss, 2008), nutrition (Melo et al., 2006) and poor quality or quantity of incident light (Sharkey and Raschke, 1981). These limitations can lead to changes in the stomatal conductance, internal gas concentration and consequently in photosynthetic activity, as well as in water use efficiency. The most efficient use of water is directly related to the time of stomatal opening, because while the plant absorbs CO_2, water is lost by transpiration, with varying intensity, depending on the potential gradient between the leaf surface and the atmosphere (Concenço et al. 2009). The photosynthetic rate is directly related to the photosynthetically active radiation (light composition), the water availability factors and gas exchange (Naves-Barbiero et al., 2000). Plants have specific light requirements, predominantly in the red and blue range (Messinger et al., 2006). If the plant does not receive these light wavelengths in a satisfactory way, it will have to adapt itself to survive (Attridge, 1990). When plants are in a state of competition for light, it also becomes important that there is a balance in the red and far-red range (Weller et al., 1997), which is affected by shading, and which influences the photosynthetic efficiency (da Matta et al., 2001). However, there are a few studies that report physiological changes in the intercropped plants. Thus, this study was conducted to evaluate the physiological characteristics of acacia and eucalyptus during their early development when grown intercropped with the *Brachiaria* forages.

Results and Discussion

Effect of intercropping in CO_2 consumption

Acacia plants grown in competition with *Brachiaria brizantha* cv. Marandu showed higher CO_2 consumption (Δ_C) compared with the treatments in which the acacia was cultivated with *B. decumbens* and *B. brizantha* cv. Piatã. In relation to the eucalyptus, all the treatments differed from the control with no competition, which showed higher values of Δ_C. On evaluating the effect of the competition in Δ_C between the tree species, no difference was observed between them for any of the forages evaluated (Table 1).

Effect of intercropped in internal carbon

Both for the acacia as well as for eucalyptus, there was a greater amount of internal carbon (C_i) in those plants grown isolated from the same forage grown in competition with the forages, and no difference was observed between the species within each forage species (Table 1). Until recently, the most accepted explanation was that light indirectly affected the stomatal aperture through its effect on CO_2 assimilation (Nishio et al., 1994). However, research has shown that the stomatal opening is less dependent on the C_i, and that they respond directly to light (Messinger et al., 2006). Thus, under conditions of competition and shading, the light balance participates in stomatal aperture control and in the balance of gases between the inside of the leaf and the external environment (Loreto and Bongi, 1989). In some studies, in sunflower plants subjected to stress, the CO_2 concentration in the substomatal cavity (C_i) increased, while the photosynthetic rate (A) was reduced (Corniani et al., 2006). In the absence of competition, the acacia and eucalyptus plants showed lower C_i, indicating the greater consumption of CO_2 (Table 1). The trees showed a higher Δ_C value, with the most evident result for eucalyptus, when not coexisting with the forage crops. The internal carbon consumption is related to a higher photosynthetic rate (A).

Effect of intercropped in transpiration rate

Acacia cultivated alone showed a higher transpiration rate (E), differing from the other treatments in which the tree species found itself in coexistence with the forages. With regard to the eucalyptus, it was found that the competition with *B. brizantha* cv. Marandu did not interfere in the E compared with the treatment in which the tree species was grown without competition at all. In all the situations of competition, the eucalyptus showed higher E values when grown simultaneously with the forages, highlighting the absence of any difference between the treatments without competition (Table 1).

Effect of intercropping in stomatal conductance of water vapor

Acacia plants grown in competition with *B. brizantha* cv. Marandu and *B. decumbens* showed a decrease in stomatal conductance (G_s), differing from plants grown in the absence of competition. Regarding the eucalyptus, only the treatment in which the *B. decumbens* was cultivated differed from the control. Eucalyptus plants cultivated with *B. brizantha* cv. Marandu showed higher G_s compared with acacia under the same conditions; however, for the other situations of coexistence with the forages, no difference between the tree species was observed (Table 1). Stomatal conductance is the physiological mechanism that vascular terrestrial plants use for transpiration control (Messinger et al., 2006). The leaf epidermis is covered by a relatively impermeable cuticle, both to water vapor as well as to carbon dioxide, and contains varying numbers of stomata, whose response, through the regulation of stomatal conductance, control leaf transpiration (Naves-Barbiero et al., 2000). According to these authors, stomatal conductance is proportional to transpiration, net photosynthesis and leaf water potential. Transpiration decline is associated with stomatal closure. Variations in the stomatal opening cause alterations in the water potential, acting on E (Brodribb and Hill, 2000). The plant tends to close its stomata when the light levels are below the level of photosynthetically active radiation or in order to avoid water stress (Cochard et al., 2002). All these parameters are linked in a cost/benefit ratio, because the E is also a mechanism used to lower leaf temperature. The processes of transpiration and CO_2 capture occur only when the stomata are open, as well as during stomatal conductance (G_s). Due to the latent heat of evaporation (energy effectively used to “heat” water and enable evaporation), transpiration has a powerful cooling effect – important in regulating leaf temperature (Farquhar and Raschke, 1978).

Effect of intercropping in photosynthetic rate

The photosynthetic rate (A) of acacia was higher when it was cultivated in the absence of competition, not differing, however, from the treatment in which the tree species grew along with *B. brizantha*, cv. Marandu; this way, *B. decumbens* and *B. brizantha*, cv. Piatã negatively affected the *A* of acacia (Table 2). According to the results documented by Ferreira et al. (2011), the *B. decumbens* shows higher efficiency in the photosynthetic characteristics and water use. These characteristics make this species highly competitive under conditions of high temperatures and luminosity. For the eucalyptus, similar to the acacia, the control showed a higher photosynthetic rate, differing from the values

Table 1. Rates of consumed CO_2, internal carbon, transpiration rate and stomatal conductance of acacia and eucalyptus plants grown in competition with forages and monocropped.

Treatments	Acacia	Eucalyptus
	Consumed CO_2 (Δ_C - µmol mol^{-1})	
Brachiaria brizantha, cv. Marandu	24.37 a A	23.90 b A
Brachiaria decumbens, cv. Basilisk	20.35 b A	20.45 b A
Brachiaria brizantha, cv. Piatã	19.52 b A	20.61 b A
Control	25.93 a A	28.76 a A
CV (%)	21.28	
	Internal carbon (C_i - µmol mol^{-1})	
Brachiaria brizantha, cv. Marandu	363.98 a A	376.30 a A
Brachiaria decumbens, cv. Basilisk	379.45 a A	371.60 a A
Brachiaria brizantha, cv. Piatã	361.40 a A	370.10 a A
Control	354.67 b A	357.10 b A
CV (%)	14.92	
	Transpiration rate (E – mol H_2O m^{-2}s^{-1})	
Brachiaria brizantha, cv. Marandu	2.66 b B	3.61 a A
Brachiaria decumbens, cv. Basilisk	2.84 b B	3.16 b A
Brachiaria brizantha, cv. Piatã	2.46 b B	3.33 b A
Control	3.58 a A	3.91 a A
CV (%)	24.17	
	Stomatal conductance (G_s – mol m^{-1}s^{-1})	
Brachiaria brizantha, cv. Marandu	0.35 b B	0.55 a A
Brachiaria decumbens, cv. Basilisk	0.36 b A	0.33 b A
Brachiaria brizantha, cv. Piatã	0.41 ab A	0.42 ab A
Control	0.53 a A	0.50 a A
CV (%)	33.56	

* Means followed by the same lowercase letter in the column and uppercase letter in the row do not differ by Tukey test at 5% significance.

Table 2. Photosynthetic rate, temperature difference, water use efficiency of acacia and eucalyptus plants grown in competition with forages.

Treatments	Acacia	Eucalyptus
	Photosynthetic rate (A - µmol m^{-2} s^{-1})	
Brachiaria brizantha, cv. Marandu	9.47 ab A	7.63 ab A
Brachiaria decumbens, cv. Basilisk	7.21 b A	6.53 b A
Brachiaria brizantha, cv. Piatã	7.95 b A	7.71 ab A
Control	11.88 a A	11.59 a A
CV (%)	31.25	
	Temperature difference (Δ_T - ^oC)	
Brachiaria brizantha, cv. Marandu	1.03 a A	1.03 a A
Brachiaria decumbens, cv. Basilisk	1.03 a A	1.04 a A
Brachiaria brizantha, cv. Piatã	1.05 a A	1.06 a A
Control	1.04 a A	1.02 a A
CV (%)	2.95	
	Water use efficiency (EUA - mol CO_2 mol H_2O^{-1})	
Brachiaria brizantha, cv. Marandu	2.86 b A	2.33 ab B
Brachiaria decumbens, cv. Basilisk	2.75 b A	1.91 b B
Brachiaria brizantha, cv. Piatã	2.87 b A	2.27 ab B
Control	3.59 a A	2.93 a A
CV (%)	28.58	

* Means followed by the same lowercase letter in the column and uppercase letter in the row do not differ by Tukey test at 5% significance.

presented by plants grown with *B. decumbens* (Table 2). The reduction in the photosynthesis of the acacia plants is related to the process of competition between the plants. The brachiaria plants, for naturally presenting a higher growth rate compared with the tree species, showed competitive advantage, being, therefore, able to take up higher amounts of water and nutrients. Under moderate water stress, the acacia and eucalyptus showed a decrease in the photosynthesis due to a decrease in the stomatal conductance, leading to stomatal closure and transpiration reduction (Grzesiak et al., 2006).

B. decumbens and *B. brizantha* are the tropical forage species of C_4 physiology, which in turn possess a specific enzyme for capturing the CO_2. It is known that the ratio between the attached CO_2 molecule to ATP to NADPH is 1:3:2 in the C_3 plants and 1:5:2 in the C_4 plants. This fact gives evidence that the latter require more energy for photoassimilate production. As all this energy comes from light, if access to this resource is reduced, these plants will lose in their competition with the C_3 plants. However, the enzyme responsible for the primary carboxylation in the C_4 plants (PEP carboxylase) has a high affinity for CO_2, acts specifically as carboxylase, has an optimal activity at higher temperatures and does not saturate at high light intensity (Taiz and Zaiger, 2004). Thus, if the crop is able to shade the forages, their growth will be reduced. In this work, as the woody plants were evaluated only up to 365 d, there was a low shading of the same in relation to the forage species, resulting in minimal influence of the luminous intensity in competition with the brachiaria.

Effect of intercropping in leaf temperature

The tree species and coexistence with the forages did not influence the leaf temperature (Δ_T) (Table 2).

Effect of intercropping in water use efficiency

Acacia plants grown isolated showed higher Water Use Efficiency (WUE) compared with the treatments in which they were competing with the forage species (Table 2). With regard to the eucalyptus, only the treatment in which the *B. decumbens* was present differed from the control for WUE. On evaluating the tree species within each treatment, it was verified that the eucalyptus competing with the forage plants showed lower WUE than the acacia plants in the same situation, not revealing any differences for this variable in the absence of competition of these tree species with the forage species evaluated (Table 2). Water use efficiency is characterized as the amount of water transpired by a plant for the production of a specific amount of dry matter. Thus, plants that are more efficient in the use of water produce more dry mass per gram of transpired water (Baptista et al., 2001). Higher efficiency in the use of water is directly linked to the time of the stomatal opening because, while the plant absorbs CO_2 for photosynthesis, water is lost to the atmosphere by evapotranspiration, following a stream of water potentials (Pereira-Netto et al., 2002). Thus, the competition for water exerted by the forage species seems to be more negative to eucalyptus compared with that for the acacia plants (Table 2).

Material and Methods

Experimental conditions

The experiment was conducted in a greenhouse, between May 2013 and May 2013, in the city of Diamantina, located in the Vale do Jequitinhonha region of Minas Gerais in the geographical coordinates of 18° 14’ South latitude, 43° 36’ West longitude. The climate of the region, according to the classification by Köppen (1948), is of the subtropical type, subtype Cwa. Characterized by mild and dry winters, it has well defined rainy and dry seasons. The annual precipitation is 1,498 mm, the average air relative humidity is 80% and the average maximum and minimum temperatures are 20.0 and 15.3°C, respectively.

Statistic design and treatments

The experiment was set up using the randomized block design with four replications and the experimental treatments consisted of a factorial arrangement (2× 4), being, respectively, two tree species (Acacia - *Acacia mangium* and Eucalyptus - *Eucalyptus urograndis*) and three forage species (*Brachiaria brizantha* cv. Marandu; *Brachiaria decumbens* cv. Basilisk and *Brachiaria brizantha* cv. Piatã) grown along with the tree species, plus the acacia and the eucalyptus grown in monocrop.

Treatments application and plant materials

Polyethylene pots with a 30 L capacity were filled with Red Yellow Latosol, clay texture, with the following chemical characteristics: pH in H_2O: 5.60, P: 1.13 (Mehlich) and K: 41.00 mg dm^{-3}, Ca^{+2}: 3.33, Mg^{+2}: 0.57 and Al^{+3}: 0.03 $cmol_c$ dm^{-3} (KCl 1 mol L^{-1}), CEC (T): 5.99 $cmol_c$ dm^{-3}, sum of the bases: 2.34 $cmol_c$ dm^{-3}, H + Al: 3.65 $cmol_c$ dm^{-3} and 2.37 dag kg^{-1} of organic matter and 20.35 of P-rem. Sowing of the *Brachiaria* forages was performed at 1.0 cm depth in trays with plastic tubes, using an agricultural substrate, with daily irrigation until 5 cm was reached. Subsequently, these were transplanted concurrently with the eucalyptus and acacia seedlings in their respective competition arrangements, being one tree seedling and three individuals of the forage species per pot. The eucalyptus and acacia seedlings showed 0.25 m height on average. The plants were irrigated daily, maintaining the soil near to 80% of field capacity. A top dressing was made every 90 days with 3 g of the formula 20-05-20 (NPK) per pot. The other plants that occurred in the pots were removed manually, to observe the effect of the treatments on only the species studied.

Physiological measurements

At 365 days after transplantation of the seedlings, evaluations were conducted in the middle third of the first fully expanded leaf of the youngest five branches of the acacia and eucalyptus plants. An Infrared Gas Analyzer (IRGA), LCA 4 model, ADC (Analytical Development Co. Ltd., Hoddesdon, UK) was used, in an open greenhouse, allowing free air circulation. The plots were evaluated between 8 and 10 am, on a single day, in order to maintain the homogeneous environmental conditions during evaluation. The variables evaluated were CO_2 consumption (Δ_C-µmolmol^{-1}), internal carbon (C_i-µmolmol^{-1}), stomatal conductance of water vapor (G_s-molm^{-1}s^{-1}), vapor pressure in the substomatal chamber, transpiration rate (E-molH$_2$Om^{-2}s^{-1}), photosynthetic rate (A-µmolm^{-2}s^{-1}), leaf temperature (Δ_T-°C) and water use efficiency (WUE - molCO$_2$molH$_2$O^{-1}) by the ratio between the amount of CO_2 fixed by photosynthesis and the amount of water transpired.

Statistical analysis

Data were subjected to the analysis of variance and the means were compared by the Tukey test at 5% probability of error.

Conclusion

The forage plants affected the photosynthetic characteristics of both the tree species negatively. *B. decumbens* was the species that promoted a negative effect on most of the variables in both acacia and in eucalyptus, presenting a greater competitive capacity among the brachiaria studied.

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