Physiological aspects of acacia and eucalyptus in competition with Brachiaria

Márcia Vitória Santos¹, Evander Alves Ferreira², Leonardo David Tuffi Santos³, Dilermando Miranda da Fonseca⁴, Ignacio Aspiazu⁵, Daniel Valadão Silva⁶, Jorge Marcelo Padovani Porto², Renan Rodrigues Braga⁶

¹Departamento de Zootecnia, Universidade Federal dos Vales do Jequitinhonha e Mucuri, Campus JK, Rodovia MGT 367 - Km 583, n° 5000 - Alto da Jacuba, Diamantina, Minas Gerais, Brasil
²Departamento de Agronomia, Universidade Federal dos Vales do Jequitinhonha e Mucuri, Campus JK, Rodovia MGT 367 - Km 583, n° 5000 - Alto da Jacuba, Diamantina, Minas Gerais, Brasil
³Instituto de Ciências Agrárias, Universidade Federal de Minas Gerais, Avenida Universitária, 1000, Bairro Universitário, 39404-006, Montes Claros, Minas Gerais, Brasil
⁴Departamento de Zootecnia, Universidade Federal de Viçosa, Avenida Peter Henry Rolfs s/n, Viçosa, Minas Gerais, Brasil
⁵Departamento de Ciências Agrárias, Universidade Estadual de Montes Claros, Av. Reinaldo Viana, 2630, Bairro Bico da Pedra, Caixa Postal 91, Januá, Minas Gerais, Brasil
⁶Departamento de Fitotecnia, Universidade Federal de Viçosa, Avenida Peter Henry Rolfs s/n, Viçosa, Minas Gerais, Brasil

*Corresponding author: danielvaladaos@yahoo.com.br

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 urophylla × grandis, intercropping systems.

Abbreviations: ΔεCO₂; consumption; Ci internal carbon; Gs stomatal conductance of water vapor; E transpiration rate; A photosynthetic rate; TA 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 CO₂, 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 CO₂ consumption

Acacia plants grown in competition with Brachiaria brizantha cv. Marandu showed higher CO₂ consumption (ΔC) 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 ΔC. On evaluating the effect of the competition in ΔC 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 (Cᵢ) 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 CO₂ assimilation (Nishio et al., 1994). However, research has shown that the stomatal opening is less dependent on the Ci 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 CO₂ concentration in the substomal cavity (Cᵢ) increased, while the photosynthetic rate (A) was reduced (Corniani et al., 2006). In the absence of competition, the acacia and eucalyptus plants showed lower Cᵢ, indicating the greater consumption of CO₂ (Table 1). The trees showed a higher ΔC 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 (Gₛ), 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 Gₛ 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 CO₂ capture occur only when the stomata are open, as well as during stomatal conductance (Gₛ). 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.
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 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 C₄ physiology, which in turn possess a specific enzyme for capturing the CO₂. It is known that the ratio between the attached CO₂ molecule to ATP to NADPH is 1:3:2 in the C₃ plants and 1:5:2 in the C₄ 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 competitive advantage, being the latter require more energy for photoassimilate production. 

Table 1. Rates of consumed CO₂, internal carbon, transpiration rate and stomatal conductance of acacia and eucalyptus plants grown in competition with forages and monocropped.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Acacia</th>
<th>Eucalyptus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consumed CO₂ (ΔC - μmol mol⁻¹)</td>
<td>Internal carbon (Ci - μmol mol⁻¹)</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Marandu</td>
<td>24.37 a A</td>
<td>23.90 b A</td>
</tr>
<tr>
<td>Brachiaria decumbens, cv. Basilisk</td>
<td>20.35 b A</td>
<td>20.45 b A</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Piatã</td>
<td>19.52 b A</td>
<td>20.61 b A</td>
</tr>
<tr>
<td>Control</td>
<td>25.93 a A</td>
<td>28.76 a A</td>
</tr>
<tr>
<td>CV (%)</td>
<td>21.28</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Transpiration rate (E - mol H₂O m⁻² s⁻¹)</th>
<th>Stomatal conductance (Gs - mol m⁻¹ s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachiaria brizantha, cv. Marandu</td>
<td>2.66 b B</td>
<td>2.27 ab B</td>
</tr>
<tr>
<td>Brachiaria decumbens, cv. Basilisk</td>
<td>2.84 b B</td>
<td>2.46 b B</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Piatã</td>
<td>2.46 b B</td>
<td>1.04 a A</td>
</tr>
<tr>
<td>Control</td>
<td>3.58 a A</td>
<td>3.91 a A</td>
</tr>
<tr>
<td>CV (%)</td>
<td>14.92</td>
<td>24.17</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Acacia</th>
<th>Eucalyptus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Photosynthetic rate (A - μmol m⁻² s⁻¹)</td>
<td>Temperature difference (ΔT - °C)</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Marandu</td>
<td>9.47 b A</td>
<td>1.03 a A</td>
</tr>
<tr>
<td>Brachiaria decumbens, cv. Basilisk</td>
<td>7.21 b A</td>
<td>1.03 a A</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Piatã</td>
<td>7.95 b A</td>
<td>1.05 a A</td>
</tr>
<tr>
<td>Control</td>
<td>11.88 a A</td>
<td>1.04 a A</td>
</tr>
<tr>
<td>CV (%)</td>
<td>31.25</td>
<td>2.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Water use efficiency (EUA - mol CO₂ mol H₂O⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachiaria brizantha, cv. Marandu</td>
<td>2.86 b A</td>
</tr>
<tr>
<td>Brachiaria decumbens, cv. Basilisk</td>
<td>2.75 b A</td>
</tr>
<tr>
<td>Brachiaria brizantha, cv. Piatã</td>
<td>2.75 b A</td>
</tr>
<tr>
<td>Control</td>
<td>3.59 a A</td>
</tr>
<tr>
<td>CV (%)</td>
<td>28.58</td>
</tr>
</tbody>
</table>

* 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.
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 ($\Delta T$) (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 CO₂ 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.

**Statistical 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. Piata) 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 H₂O: 5.60, P: 1.13 (Mehlich) and K: 41.00 mg dm⁻³, Ca: 2³; 3.33, Mg: 2²; 0.57 and Al: 1²; 0.03 cmol, dm⁻³ (KCI 1 mol L⁻¹), CEC (T): 5.99 cmol, dm⁻³, sum of the bases: 2.34 cmol, dm⁻³, H + Al: 3.65 cmol, 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 CO₂ consumption ($\Delta T$ - µmolmol⁻¹), internal carbon ($C_i$ - µmolmol⁻¹), stomatal conductance of water vapor ($G$ - µmolm⁻²s⁻¹), vapor pressure in the substomatal chamber, transpiration rate ($E$ - molH₂O·m⁻²s⁻¹), photosynthetic rate ($A$ - µmolm⁻²s⁻¹), leaf temperature ($\Delta T$-C) and water use efficiency (WUE - molCO₂·molH₂O⁻¹) by the ratio between the amount of CO₂ 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.

**Acknowledgements**

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and the Research Foundation of the State of Minas Gerais (FAPEMIG) for financial support and for scholarships granted.

**References**


água. Lisboa: Instituto Superior de Agronomia, pp 212