PHOTOSYNTHETIC ACTIVITY OF CASSAVA PLANTS UNDER WEED COMPETITION[1]

Atividade Fotossintética de Plantas de Mandioca Submetidas a Competição com Plantas Daninhas

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ABSTRACT - The objective of this work was to evaluate characteristics associated with the photosynthetic activity of cassava plants under weed competition. The trial was carried out under field conditions, and experimental units consisted of 150 dm^3 fiberglass boxes containing red yellow Latosol, previously corrected and fertilized. Treatments consisted in the cultivation of cassava plants which were free of weed competition and associated with three weed species: *Bidens pilosa*, *Commelina benghalensis* or *Brachiaria plantaginea*. After manioc sprouting started, 15 days after being planted, weeds that had been sown when manioc was planted were thinned, there were then eight plants left per experimental unit in accordance with specified treatments: cassava free of competition, cassava competing with *B. pilosa*, cassava competing with *C. benghalensis* and cassava competing with *B. plantaginea*. Sixty days after crop emergence leaf internal CO_2 concentration (Ci), leaf temperature at the time of evaluation (T_{leaf}) and photosynthetic rate (A) were evaluated, also the CO_2 consumption rate (ΔC) of cassava plants was calculated. A correlation matrix between variables was also obtained. All characteristics associated with photosynthesis in cassava plants were influenced by weed species. Cassava was more affected by *B. pilosa* and *B. plantaginea* in which concerns its exposition to solar radiation and water, while *C. benghalensis* seems to mostly affect the composition of incident light on the culture, allowing cassava to anticipate imposition when competing, even before it reaches harmful levels.

Keywords: interference, *Bidens pilosa, Commelina benghalensis, Brachiaria plantaginea*, physiological variables.

*RESUMO - Objetivou-se com este trabalho avaliar características associadas à atividade fotossintética de plantas de mandioca sob competição ou não com plantas daninhas. O experimento foi realizado em condições de ambiente aberto, sendo as unidades experimentais compostas por vasos de fibra de vidro de 150 dm^3 preenchidos com Latossolo Vermelho Amarelo, previamente adubado. Os tratamentos consistiram no cultivo de plantas de mandioca isoladas e associadas a três espécies daninhas (**Bidens pilosa**, **Commelina benghalensis** e **Brachiaria plantaginea**). Após início da brotação das manivas, 15 dias após o plantio, fez-se o desbaste das plantas daninhas, semeadas no momento do plantio das manivas, deixando-se oito plantas de **B. pilosa**, quatro de **C. benghalensis** e quatro de **B. plantaginea**. Aos 60 dias após a brotação das manivas, avaliou-se a concentração de CO_2 interna na folha (Ci), temperatura da folha no momento da avaliação (T_{leaf}) e a taxa fotossintética (A), sendo calculado também o CO_2 consumido (ΔC) referentes às plantas de mandioca. Foi elaborada ainda matriz de correlação entre as variáveis. Todas as características avaliadas foram influenciadas*

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*pela espécie de planta daninha em competição com a cultura. A mandioca foi mais afetada por **B. pilosa** e **B. plantaginea** em relação ao acesso à radiação solar e água, enquanto **C. benghalensis** parece afetar mais a composição da luz incidente sobre a cultura, permitindo que a mandioca possa antecipar a imposição da competição, mesmo antes que atinja níveis prejudiciais*

Palavras-chave: interferência, *Bidens pilosa*, *Commelina benghalensis*, *Brachiaria plantaginea*, variáveis fisiológicas.

INTRODUCTION

Interspecific and intraspecific plant competition affect the amount and the quality of the final product, as well as its efficiency in utilization of environmental resources (VanderZee & Kennedy, 1983; Melo et al., 2006). This is noted when assessing physiological characteristics associated to photosynthesis, such as concentration of internal and external gases (Kirschbaum & Pearcy, 1988), light composition and intensity (Sharkey & Raschke, 1981) and mass accumulation by plants under different conditions.

Although gas exchange capability by stomata is considered a main limitation for photosynthetic CO_2 assimilation (Hutmacher & Krieg, 1983), it is unlikely that gas exchange will limit the rate of photosynthesis when interacting with other factors. However, photosynthetic rate is directly related to the photosynthetically active radiation (composition of light), to water availability and gas exchange (Naves-Barbiero et al., 2000). Plants have specific needs for light, predominantly in bands of red and blue (Messinger et al., 2006). When plants do not receive these wave lengths in a satisfactory manner, they need to adapt themselves in order to survive (Attridge, 1990). When under competition for light, the red and far-red ratio affected by shading is also important (Weller et al., 1997) and influences photosynthetic efficiency (Da Matta et al., 2001).

The objective of this work was to evaluate characteristics associated to the photosynthetic activity of cassava plants under weed competition.

MATERIAL AND METHODS

The trial was conducted in the Experimental Field Professor Diogo Alves de Mello, Departmento de Fitotecnia (DFT, Universidade Federal de Viçosa (UFV), Brazil. The experimental units were fiberglass vases with capacity for 150 $dm^3$of Red Yellow Latosol previously fertilized according to recommendations of Cantarutti et al. (2007). All vases were drilled at the bottom and filled with 5 cm of crushed stone before being filled with soil, in order to drain the excess of water from rain or irrigation. Throughout the experimental period, soil moisture was kept at about 2/3 of field capacity by periodical irrigation according to the needs.

One cassava stem cutting of about 15 cm in length was planted in each plot for the experiment, as well as weeds, according to treatments. When cassava emerged weeds were standardized to such desired densities: *Bidens pilosa* (three plants m^{-2}), *Brachiaria plantaginea* (six plants m^{-2}) or *Commelina benghalensis* (transplanted by seedlings - three plants m^{-2}). The experimental design was completely randomized blocks with three replications, in a 3 x 8 factorial scheme. Weeds from soil seed bank were removed manually every week. Weed densities on the experimental units were defined by consulting experts in this area.

Sixty days after crop emergence (DCE), physiological parameters were evaluated by using an Infrared Gas Analyzer (LCA-4 - ADC Bioscientific, Herts, UK). These tests were performed in the younger fully expanded cassava leaf, between 8:00 and 10:00a.m. Only one block was evaluated per day, in order to maintain environmental conditions as homogeneous as possible. Leaf internal CO_2 concentration (Ci - $\mu mol\ mol^{-1}$), leaf temperature at the evaluation time (Tleaf - ^oC) and photosynthetic rate (A - $\mu mol\ m^{-2}\ s^{-1}$) were evaluated, and CO_2 consumption (ΔC - $\mu mol\ mol^{-1}$) was calculated from the reference values of CO_2 and CO_2 inside the evaluation chamber.

Data were submitted to analysis of variance through F-test, and when there was significance means, they were then compared in pairs through the test of least significant difference (LSD). All tests were performed at 5% level using the statistical software SAEG. Among the variables studied, Pearson correlations were calculated between evaluated parameters, and tested through t-test.

RESULTS AND DISCUSSION

Cassava plants grown free of competition showed greater (P<0.05) leaf internal CO_2 concentration (Ci) than when competing with weeds (Table 1). Lower CO_2 concentrations (P<0.05) in leaves were observed when cassava plants were grown under competition with *C. benghalensis*. Ci is considered a physiological variable, influenced by species, but also highly dependent on environmental factors such as availability of water and light, among others (Ometto et al., 2003). The highest values (P<0.05) for Ci observed in cassava plantswere when under competition with *B. pilosa* or *B. plantaginea*, if compared to *C. benghalensis*. That can be attributed to the accelerated plant metabolism as a way to increase growth rate and escape shading caused by weeds. It is believed that under these conditions, where lower Ci occurs, CO_2 was consumed due to the increase in the metabolic rate. The effect of *C. benghalensis* on Ci of cassava plants was not very striking, since it only motivated cassava to recognize its imposition in competition, and stimulate its metabolism in order to increase its competitive capacity.

The quality of light regulates many processes in plants, such as germination, morphogenesis and flowering (Young & Smith, 1989; Ballaré et al., 1992). The morphological responses are well known and include pronounced stem elongation, reduction in dry weight proportion of leaf/stem, and reduction in tillering. It has been shown that these responses are triggered by phytochrome in response to low Red:Far Red (R:FR) ratios in the canopy (Smith, 1982). Researches conducted by Ballaré, Young and colleagues showed that responses to changes in R:FR ratios occur before the mutual shading among neighbors. Based on that work, it was proposed that the Far Red radiation, which is reflected by adjacent leaves, is a means of early detection that signals the imminence of competition during canopy development (Ballaré et al., 1990, 1992; Holt, 1995; Merotto Jr. et al., 2009). In addition, some species are capable of recognizing others by the amount of radiation reflected in each wave length (Larcher, 2006). It was probably what happened when cassava plants competed with *C. benghalensis*; the presence of this weed species might have been simply enough to increase cassava metabolism as a way to avoid the imposition of future competition. Since resources such as light *B. Pilosa* and *B. plantaginea* show rapid growth and high capacity to consume environment resources efficiently, while *C. benghalensis*, is a species that survives in less disturbed environments. According to Grime (1979), competition is a way neighboring plants use the same resources, and success in competition is strongly determined by the plant capacity to capture these resources. Thus, a good competitor has a high relative growth rate

Table 1 - Characteristics associated with cassava plants use of water 60 days after emergence, in function of weed infestation. Viçosa-MG, 2008

Treatment	Ci (μmol mol^{-1})	ΔC (μmol mol^{-1})	T_{leaf} (°C)	A (μmol m^{-2} s^{-1})
Cassava	295,7 a[1/]	14,43 b	32,1 b	5,71 b
Cassava x *B. pilosa*	256,4 b	12,73 b	33,6 ab	5,17 b
Cassava x *C. benghalensis*	232,3 c	19,60 a	35,1 a	7,32 a
Cassava x *B. plantaginea*	266,9 b	14,50 b	33,6 ab	5,93 b
CV (%)	10,0	19,4	3,6	15,2

[1/] Means followed by same letter, in same column, do not differ through Fisher's LSD test at 5% probability. Ci = leaf internal CO_2 concentration; ΔC = CO_2 consumed during evaluation; T_{leaf} = leaf temperature; A = photosynthetic rate.

and can use the available resources quickly. However, Tilman (1980) claims that competitive success is the ability to extract scarce resources and to tolerate this lack of resources. Therefore, in theory, a good competitor could be the species with least resource requirement (Radosevich et al., 1997).

Light affects stomatal opening indirectly through its effect on CO_2 assimilation (Sharkey & Raschke, 1981; Nishio et al., 1994). However, stomatal opening is less dependent on Ci, and responds directly to light (Radosevich, 1997). Thus, under competing and shading conditions, the stability of light is involved in controlling stomatal opening, as well as the balance between the gas in the interior of the leaf and on the environment (Tallman & Zeiger, 1988; Loreto & Bongi, 1989). In studies with sunflower plants subjected to water stress, leaf internal CO_2 concentration (Ci) increased, while the photosynthetic rate (A) reduced. When the stress agent was removed, the plant recovered, and both photosynthetic capacity and Ci were normalized (Corniani et al., 2006).

The consumption of CO_2 (ΔC) increased proportionally to the decrease of Ci. That means that the higher the ΔC in the mesophyll, the higher the gradient created between the interior of the leaf and the environment. When the three weeds were compared, *C. benghalensis* was the one that least ($P<0.05$) affected cassava plant consumption of $CO_{2,}$ because there was a higher gradient between the internal and the external sides of the cassava leaves. This is due mainly to the metabolism stimulus caused by low competition between crop and weeds. *B. pilosa* and *B. plantaginea*, on the other hand, it affected cassava plant in a way that, even under competition, and when their metabolism should have been stimulated, no differences were observed ($P>0.05$) regarding the competition-free control.

Cassava leaves temperature was higher when in competition with *C. benghalensis*, mainly due to the stimulus in metabolism caused by the presence of weed, and due to the low competition exerted, or simply due to the changing of the quality of light, which allowed cassava plants to recognize the species of weed (Radosevich et al., 1997; Larcher, 2006). The competition-free control indicates the metabolic rate usual to cassava plants when free of competition. In this situation, plant growth becomes more balanced, distributing photoassimilates proportionally between shoots and roots, which is not the case when under competition (Radosevich et al., 1997). Plant metabolism causes an increase in leaf temperature, therefore leaf temperature is usually higher than the temperature of the air around it. Thus, metabolism increases can be indirectly measured as a function of leaf temperature. The difference between leaf temperature and the air around it is commonly only 1 or 2 ºC, but in extreme cases it may exceed 5 °C (Atkin et al., 2000). Cassava plants under competition with *B. pilosa* or *B. plantaginea* stayed half way compared to the ones observed in weed-free control, and at treatment under competition with *C. benghalensis*. This indicates that these weeds were able to prevent cassava from reacting adequately to the imposition of competition, probably by limiting crop access to appropriate levels of a given resource, such as light or water, for example.

Photosynthesis, and therefore respiration, depends on the constant flow of CO_2 and of O_2 in and out of the cell; this free flow is function of the concentration of CO_2 and O_2 in the intercellular spaces depending on stomatal opening, main controller of the gas flux (Messinger et al., 2006). This, in turn, is largely controlled by turgescence of both guard-cells (which control stomatal opening) and stomatal epidermal cells (Humble & Hsiao, 1970). Low water potentials induce stomatal closure and reduce leaf conductance,

Table 2 - Pearson linear correlation matrix in function of the characteristics associated with the phtosynthesis of cassava plants 60 days after emergence. Viçosa-MG, 2008

	Ci (μmol mol^{-1})	ΔC (μmol mol^{-1})	T_{leaf} (°C)	A (μmol m^{-2} s^{-1})
Ci	-			
ΔC	-0,60*	-		
T_{leaf}	-0,53	0,34	-	
A	-0,60*	0,96*	0,37	-

* = significant through t test ($P<0,05$). Ci = leaf internal CO_2 concentration; ΔC = CO_2 consumed during evaluation; T_{leaf} = leaf temperature; A = photosynthetic rate.

inhibiting photosynthesis and transpiration and usually resulting in increased leaf temperature (Attridge, 1990).

The photosynthetic rate was also higher ($P<0.05$) for cassava plant under competition with *C. benghalensis*, when compared to other treatments. According to Merotto Jr. et al. (2009), changes in the quality of light caused by weeds is a factor that affects crop development. Photosynthetic rate of cassava under competition with *C. benghalensis* was 7.32 μmol m^{-2} s^{-1} CO_2, while for the average of the remaining treatments was 5.50 μmol m^{-2} s^{-1} CO_2. The radiation balance and composition on the plant when in competition or shading, combined with carbohydrate level in leaves, may increase respiratory rate directly or through alternative pathways associated with the respiratory chain (Pystina & Danilov, 2001). This could make photosynthesis balance even smaller and reduce the ability of the plant to accumulate mass. Several species of weed and commercial crops change their photosynthetic rate at different levels under the same environmental conditions (Procópio et al., 2004).

Generally, thephotosynthetic characteristics of cassava were influenced by its competition with *B. pilosa* and *B. plantaginea*. We have noticed that cassava plants are affected by these species of weed especially concerning its exposition to light and water. However, there were no negative effects when cassava plants competed with *C. benghalensis*. This species seems to rather affect the composition of light by reflecting peculiar spectrum of specific wavelengths, which allows cassava plants to anticipate the imposition of competition even before they get to harmful levels.

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