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Jacqueline Braga
MSc. Pós Graduate Student - PPGRNA- Federal University of Western Pará - UFOPA, Campus Tapajós, Santarém, Pará, Brazil

Dr Patricia Chaves de Oliveira
Associate Professor of Federal University of Western Pará- UFOPA, Biodiversity and Forest Institute, Campus Tapajós, Santarém, Pará, Brazil

Correspondence
Dr Patricia Chaves de Oliveira
Associate Professor of Federal University of Western Pará- UFOPA, Biodiversity and Forest Institute, Campus Tapajós, Santarém, Pará, Brazil

Leaf Stomatal behavior of useful plant species to Borari indigenous people - Novo Lugar Community, Pará-Brazil

Jacqueline Braga and Dr Patricia Chaves de Oliveira

Abstract
Stomatal control is an important mechanism by which plants limit water loss by closing them. Because of this capacity, the stomatal conductance is the variable that first responds to critical climate changes, so it is usually associated with the stress scenarios. However, the ecophysiological study of stomatal responses even in environments with good water supply is necessary, especially in species of high cultural value, which represent a source of subsistence for several indigenous families. The objective of this study was to characterize the stomatal behavior of nine species: Andiroba (*Carapa guianensis* Aubl.), Purple cotton (*Gossypium arboreum* L.), banana (Musa sp.), Buriti (*Mauritia flexuosa* L.), cupuaçu (Theobroma (*Ingr heterophylla* Willd.), murici (*Byrsonima crassifolia* (L.) Kunth) and Urubucaá (*Aristolachia trilobata* L.), species of high cultural value to Borari indigenous people, community of Novo Lugar, Santarém-Pará, Brazil. In order to do so, eight completely expanded leaves from each of the nine species were randomly selected to read the stomatal conductance at three different times (08: 00-9: 00a.m., 11: 00-12: 00 a.m. and 05: 00- 06:00 p.m.) by use of a Porometer AP4 (ΔT Devices, Cambridge, England). The results suggest that there are significant differences ($p < 0.0001$) in the stomatal conductance between species, which can be explained by the physiological plasticity inherent to each specie.

Key words: physiology, pore size, cultural value

Introduction

Stomatal responses can considered as bio indicators because through the gaseous conductance it is possible to detect environmental changes (Hetherington and Woodward, 2003) [7]. With of stomatal behavior its possible infer if a species is more tolerant or more sensitive to water stress (Mc Dermit, 1990 (Brunini *et al*., 2011) [10], as the water potential decreases, the stomatal resistance to gas exchange increases (Brunini and Cardoso 1998) [1]; (Fig. 1).

Thus, water being an essential component for the development of plants (Nogueira *et al*., 2001; Pinto, 2006) [11, 13]; the study of stomatal conductance is usually related to situations of water stress (Rocha and Moraes 1997; Brunini and Cardoso, 1998) [14, 1]. However, the stomatal characterization of species of great economic or cultural interest is necessary even in conditions of good water supply. Whereas in the rainy season other factors may have greater influence on the mechanics of opening and closing stomata; such as temperature, relative air humidity and CO_2 concentration (Lima, 1993), and the environment (Drake, *et al*. (Fig. 2). The results obtained in this work summarized in the following table (Rodrigues *et al*., 2011) [15].

The stomatal characterization can also help to understand the physiological behavior of the species in the face of critical situations. According to Calbo and Moraes (2000), even plants that have wet local habitats can submitted to water deficit in drier years. For Hetherington and Woodward (2003) [7], stomata are a key tool for understanding how plants respond to environmental changes, as well as for understanding plant evolution itself. In addition, because they are involved in the uptake of CO_2 and contribute to the process of photosynthesis (Jarvis and Davies 1998) [8], the functioning of stomata influences plant productivity (Costa and Marenco 2007) [4]. They also act on the hydrological cycle since some of the pricipated water returns to atmosphere through the transpiration by stomata (Salati *et al*., 1979) [16]. Thus, reductions in stomatal conductance may affect a series of plant-environment interactions, since stomata exert control over water vapor and energy balance between the plant and environment (Brunini and Cardoso 1998) [1].

In this context, the objective of this work is to characterize the stomatal responses of nine species of high cultural value to indigenous people at Novo Lugar Community, in order to contribute to their conservation, since physiological studies provides subsidies for the management of indigenous agroecosystems for better local resources exploitation.

Methodology

The community of Novo Lugar (55.8º W, 2.9º S) is located on the left bank of Maró River, a tributary of the Arapiuns River, in front of the Tapajós-Arapiuns Extractive Reserve, in Santarém city, in western Pará. Gleba Nova Olinda I composed of 14 communities, of which three are indigenous: São José, Cachoeira do Maró and Novo Lugar, which form the indigenous land of Maró, currently under legalization process, covering an area of approximately 42,373 ha. The groups identified as Arapiuns and Borari ethnicity. The Borari indigenous of Novo Lugar community presents a traditional way of life whose livelihood based on extractivism. The forest plays a fundamental role in the lives of their families, even contributing to their health, since traditional (homemade) medicines are the main means of treatment for various diseases. In addition, the forest is also a source of food, since the community lives mainly from the collection of products from this, such as fish and products from the itinerant cassava agriculture and regional crops. Families also use a large number of species to obtain various products for domestic use, such as vines, stalks, resins, seeds, leaves and roots. Almost there is no commercialization of production, the circulation of currencies is low, the Indigenous have difficulties to guarantee their own economy, but the sale of cassava flour as one of the sources of income is the main activity for this purpose (Health Project and Joy 2011) [13].

The climate of Santarém according to the classification of Köppen is type Am (Tsukamoto Filho *et al*., 2007) [19], with annual precipitations ranging from 1900 to 2100 mm. The region also presents moderate dry season with average precipitation of less than 60 mm and average air temperature between 25.9 and 26 °C. The relative humidity is quite high, with values around 84.1 and 86% and sunshine around 1900 to 2000 (Uchôa, 2011) [20].

The vegetation of the Maró River region is predominantly composed of land forest formed by subperenifolia equatorial forest and some subperenifolia equatorial Cerrado enclaves. However, there is also an “igapó” (flooded) forest with hygroscopic equatorial forest and hygroscopic equatorial fields (IDEFLOR, 2009).

Selection of species done through the application of a semi-structured questionnaire in order to raise the species used for various purposes in the community of Novo Lugar. The most frequently mentioned species were andiroba (Carapa guianensis Aubl.), Purple cotton (Gossypium arboreum L.), banana (Musa sp.), Buriti (Mauritia flexuosa L.), cupuaçu (Theobroma grandiflorum Schum), guava (Psidium guajava L. (Inga heterophylla Willd.), murici (Byrsonima crassifolia (L.) Kunth) and Urubucaá (Aristolachia trilobata L.).

The characterization of stomatal responses performed on a single day in February, which corresponds to the rainy season of the region. Eight completely expanded and asymptomatic leaves randomly selected from each of the nine species useful to the Novo Lugar community. On each leaf, readings on stomatal conductance taken at three different times (08:00 - 09:00, 11:00 - 12:00 a.m. and 05:00 - 06:0p.m.) with the aid of an AP4 (ΔT Devices, Cambridge, England).

The statistical analysis of the data obtained through the BioEstat 5.0 program, through descriptive statistics, analysis of variance (ANOVA), one and two criteria and factorial analysis a x b.

Results and Discussions

The descriptive statistics (Table 1) for nine species Andiroba (Carapa guianensis Aubl.), Purple cotton (Gossypium arboreum L.), banana (Musa sp.), Buriti (Mauritia flexuosa L.), cupuaçu (Theobroma grandiflorum Schum) guava (Psidium guajava L.), ingá xixi (Inga heterophylla Willd.), murici (Byrsonima crassifolia (L.) Kunth) and Urubucaá (Aristolachia trilobata L.) obtained from 08:00 to 09:00 h, showed that of the nine species studied, buriti indicates that it is the species with the highest stomatal control, since it presented a lower rate than the others (90, 62 mmol m-2s1-).

Table 1: Descriptive Statistics of leaf stomatal conductance (gs mmol H_2O / m^2s) of nine useful plant species: 1.andiroba (*Carapa guianensis* Aubl.), 2.alodao (*Gossypium arboreum* L.), 3.banana (*Musa sp*.), 4.buriti (*Mauritia flexuosa* L.), 5.cupuaçu (*Theobroma grandiflorum* Schum), 6.goiaba (*Psidium guajava* L.), 7.ingá xixi (*Inga heterophylla* Willd.), 8. Murici (*Byrsonima crassifolia* (L.) Kunth) and 9.urubucaá (*Aristolachia trilobata* L.), at Novo Lugar community, collected at 08-09: 00 a.m.

Specie	- 1 – Algod.	- 2 -Andiroba	- 3 – Banana	- 4 – Buriti	- 5 -Cupuaçu	- 6 – Goiaba	- 7 – Ingá xixi	- 8 – Murici	- 9 -Urubucaá
Sample	8	8	8	8	8	8	8	8	8
Mínimun	123.0	117.0	137.0	26.0	98.0	95.0	39.0	103.0	177.0
Maximum	355.0	335.000	350.00	169.00	200.00	244.00	228.00	290.00	375.000
Total range	223.0	218.0	213.00	143.00	102.00	149.00	189.00	187.00	198.000
Arit. average	210.8	244.875	233.50	90.625	143.5	169.12	116.50	172.37	250.000

According to Calbo and Morais 1997 [2], buriti (*Mauritia flexuosa*) has mechanisms to tolerate moderate drought. On the other hand, the species that presented the highest rates (250 mmol m-2s1) for this period was Urubucaá, indicating that it does not have strategies for saving water and exudes freely in the first hours of the day. This behavior may related to the region's rainy season, where soils well supplied with water. The same observed by Tatagiba *et al*. (2007), when studying the physiological behavior of Eucalyptus clones. They attributed the high transpiration rates to the available water surplus in the soil during the rainy season. Additionally, according to Kallarackal and Somen (1997) [6], in the morning, higher values of stomatal conductance generally observed.

However, when the nine species were analyzed in the period of 11: 00-12: 00 h (Table 2), it was observed that the banana (*Musa sp*.) had a lower conductance average (122.62 mmol m-2s1) and was therefore a very efficient species in the control of perspiration in the hottest period of the day.

Table 2: Descriptive Statistics of leaf stomatal conductance (gs mmol H_2O / m^2s) of nine useful plant species: 1.andiroba (*Carapa guianensis* Aubl.), 2.alodao (*Gossypium arboreum* L.), 3.banana (*Musa sp*.), 4.buriti (*Mauritia flexuosa* L.), 5.cupuaçu (*Theobroma grandiflorum* Schum), 6.goiaba (*Psidium guajava* L.), 7.ingá xixi (*Inga heterophylla* Willd.), 8. Murici (*Byrsonima crassifolia* (L.) Kunth) and 9.urubucaá (*Aristolachia trilobata* L.), at Novo Lugar community, collected at 11-12: 00 a.m.

Specie	- 1 - Algodão	- 2 -Andiroba	- 3 – Banana	- 4 – Buriti	- 5 -Cupuaçu	- 6 – Goiaba	- 7 – Ingá	- 8 – Murici	- 9 -Urubucaá
Sample	8	8	8	8	8	8	8	8	8
Mínimun	127.0	131.000	97.000	117.00	126.00	136.00	80.000	214.00	139.000
Maximum	325.0	184.000	158.00	200.00	240.00	240.00	246.00	620.00	570.000
Total range	198.0	53.0000	61.000	83.000	114.00	104.00	166.00	406.00	431.000
Arit. average	213.8	154.250	122.62	137.62	180.75	183.37	148.37	354.62	308.000

Cayón (2004) [3] argues that optimal temperatures for banana (*Musa sp*.) trees are between 18 and 38 °C. In this sense, it believed that the temperature influenced the stomatal control evidenced by the banana in this study, since it was in the optimum temperature range. The same author also points out that temperature is a determinant factor for banana growth and development due to its effect on metabolic processes, which in turn exerts a direct influence on photosynthetic and respiratory activity.

Also during the hours of 11: 00-12: 00a.m., Murici (*Byrsonima crassifolia*) presented high conductance (354, 62 mmol m-2s1), indicating that in drought scenarios, this species would be more sensitive to water stress because it does not present stomatal control strategies and loses a lot of water. This fact leads a loss of leaf turgidity, since even on cloudy days the Deficit of Vapor Pressure (DPV) increases considerably at this time. On the other hand, Sarmiento *et al*. (1985) [17] argue that in periods of drought *B. crassifolia* maintains stomatal conductance and transpires freely, even with little availability of water. To do so, the species invests in the growth of its roots to reach water in deeper layers of soil. The same behavior observed at 17:00.-18:00 p.m. (Table 3), where the banana (*Musa sp*.) showed the lowest rates (49.42 mmol m-2s1) and the highest mortality (375.87 mmol m- 2s1), even in relation to the previous period.

Table 3: Descriptive Statistics of leaf stomatal conductance (gs mmol H_2O / m^2s) of nine useful plant species: 1.andiroba (*Carapa guianensis* Aubl.), 2.alodao (*Gossypium arboreum* L.), 3.banana (*Musa sp*.), 4.buriti (*Mauritia flexuosa* L.), 5.cupuaçu (*Theobroma grandiflorum* Schum), 6.goiaba (*Psidium guajava* L.), 7.ingá xixi (*Inga heterophylla* Willd.), 8. Murici (*Byrsonima crassifolia* (L.) Kunth) and 9.urubucaá (*Aristolachia trilobata* L.), at Novo Lugar community, collected at 05-06: 00 p.m.

Specie	- 1 - Algod	- 2 –Andirob.	- 3 – Banana	- 4 – Buriti	- 5 -Cupuaçu	- 6 – Goiaba	- 7 – Ingá	- 8 – Murici	- 9 –Urubuc.
Sample	8	8	8	8	8	8	8	8	8
Mínimun	262.0	33.0000	13.800	58.000	127.00	70.000	50.000	198.00	113.000
Maximum	560.0	112.000	100.0	172.00	228.00	161.00	182.00	550.00	320.000
Total range	298.0	79.0000	86.20	114.00	101.00	91.000	132.00	352.00	207.000
Arit. average	375.6	70.187	49.425	127.87	171.37	113.87	110.37	375.87	211.375

The analysis of variance (Table 4), showed that the conductance variation does not occur as a function of the period of the day, since this relationship was not significant (p = 0.651) from the statistical point of view.

Table 4: Analysis of variance, 2 criteria, through the Tukey test to compare the stomatal conductance (gs mmol H_2O / m^2s) in leaf tissues of nine species; *Carapa guianensis* Aubl.), algodão roxo (*Gossypium arboreum* L.), banana (*Musa sp*.), buriti (*Mauritia flexuosa* L.), cupuaçu (*Theobroma grandiflorum* Schum), goiaba (*Psidium guajava* L.), ingá xixi (*Inga heterophylla* Willd.), murici (*Byrsonima crassifolia* (L.) Kunth) and urubucaá (*Aristolachia trilobata* L.) at different hours a day (08-09:00a.m.; 11-12:00 a.m. e 5:00-06:00 p.m.), Novo Lugar community, Santarém, Pará, Brazil.

Sources of Variation	Liberty Degree
Treatments (Hours Day)	2
Blocks (Specie)	8
F (treatments) =	0.4488
P (treatments) =	0.6511
F (Blocks) =	2.5183
P (Specie) =	0.0549*

* (significative $p<0.05$)

This result can attributed to the fact that the measurements made during the rainy season and the cloudy weather. However, when analyzing variation in stomatal conductance between species, significant differences were observed (p = 0.0549). Therefore, the variations in the conductance are in function of the physiology of each species. Thus, corroborating with the verified, Carneiro *et al*. (2008) clarify that the physiological factors associated with environmental conditions control the intensity of the stomatal opening. In this case, only the physiological differences between plants respond by variation in stomatal conductance. On the other hand, the analysis of variance (ANOVA), by Tukey's test shows the variations between species in each period of the day (Table 5, 6 and 7 respectively). This test shows significant differences (p <0.0001) in the stomatal conductance of the species in each of the evaluated schedules.

Table 5: Analysis of variance, 1 (one) criteria, through the Tukey test to compare the stomatal conductance (gs mmol H_2O / m^2s) in leaf tissues of nine species; *1.Carapa guianensis* Aubl.), 2. Algodão roxo (*Gossypium arboreum* L.), 3.banana (*Musa sp*.), 4.buriti (*Mauritia flexuosa* L.), 5.cupuaçu (*Theobroma grandiflorum* Schum), 6.goiaba (*Psidium guajava* L.), 7.ingá xixi (*Inga heterophylla* Willd.), 8.murici (*Byrsonima crassifolia* (L.) Kunth) and 9.urubucaá (*Aristolachia trilobata* L.) at 08-09:00 a.m., Santarém, Pará, Brazil.

Sources of Variation			
Treatments	8		
(p) =	< 0.0001		
Tukey:	Difference	Q	(p)
Average (1 a 4) =	120.2500	5.3117	< 0.05
Average (2 a 4) =	154.2500	6.8135	< 0.01
Average (2 a 7) =	128.3750	5.6706	< 0.01
Average (3 a 4) =	142.8750	6.3111	< 0.01
Average (3 a 7) =	117.0000	5.1681	< 0.05
Average (4 a 9) =	159.3750	7.0399	< 0.01
Average (5 a 9) =	106.7500	4.7154	< 0.05
Average (7 a 9) =	133.5000	5.8970	< 0.01

Tabela 6: Analysis of variance, 1 (one) criteria, through the Tukey test to compare the stomatal conductance (gs mmol H_2O / m^2s) in leaf tissues of nine species; *Carapa guianensis* Aubl.), algodão roxo (*Gossypium arboreum* L.), banana (*Musa sp*.), buriti (*Mauritia flexuosa* L.), cupuaçu (*Theobroma grandiflorum* Schum), goiaba (*Psidium guajava* L.), ingá xixi (*Inga heterophylla* Willd.), murici (*Byrsonima crassifolia* (L.) Kunth) and urubucaá (*Aristolachia trilobata* L.) at 11-12:00 a.m., Santarém, Pará, Brazil.

Sources of Variation			
Treatments	8		
(p) =	< 0.0001		
Tukey:	Difference	Q	(p)
Average (1 a 8) =	140.7500	5.0498	< 0.05
Average (2 a 8) =	200.3750	7.1890	< 0.01
Average (2 a 9) =	153.7500	5.5162	< 0.01
Average (3 a 8) =	232.0000	8.3237	< 0.01
Average (3 a 9) =	185.3750	6.6509	< 0.01
Average (4 a 8) =	217.0000	7.7855	< 0.01
Average (4 a 9) =	170.3750	6.1127	< 0.01
Average (5 a 8) =	173.8750	6.2383	< 0.01
Average (5 a 9) =	127.2500	4.5655	< 0.05
Average (6 a 8) =	171.2500	6.1441	< 0.01
Average (7 a 8) =	206.2500	7.3998	< 0.01
Average (7 a 9) =	159.6250	5.7270	< 0.01

Table 7: Analysis of variance, 1 (one) criteria, through the Tukey test to compare the stomatal conductance (gs mmol H_2O / m^2s) in leaf tissues of nine species; *Carapa guianensis* Aubl.), algodão roxo (*Gossypium arboreum* L.), banana (*Musa sp*.), buriti (*Mauritia flexuosa* L.), cupuaçu (*Theobroma grandiflorum* Schum), goiaba (*Psidium guajava* L.), ingá xixi (*Inga heterophylla* Willd.), murici (*Byrsonima crassifolia* (L.) Kunth) and urubucaá (*Aristolachia trilobata* L.) at 05-06:00p.m., Santarém, Pará, Brazil.

Sources of Variation			
(p) =	< 0.0001		
Tukey:	Diferença	Q	(p)
Average (Specie 1 a 2) =	305.4375	12.2226	< 0.01
Average (1 a 3) =	326.2000	13.0535	< 0.01
Average **(** 1 a 4) =	247.7500	9.9142	< 0.01
Average (1 a 5) =	204.2500	8.1734	< 0.01
Average (1 a 6) =	261.7500	10.4744	< 0.01
Average (1 a 7) =	265.2500	10.6145	< 0.01
Average (1 a 9) =	164.2500	6.5728	< 0.01
Average (2 a 8) =	305.6875	12.2326	< 0.01
Average (2 a 9) =	141.1875	5.6499	< 0.01
Average (3 a 5) =	121.9500	4.8800	< 0.05
Average (3 a 8) =	326.4500	13.0635	< 0.01
Average (3 a 9) =	161.9500	6.4807	< 0.01
Average (4 a 8) =	248.0000	9.9242	< 0.01
Average (5 a 8) =	204.5000	8.1834	< 0.01
Average (6 a 8) =	262.0000	10.4844	< 0.01
Average (7 a 8) =	265.5000	10.6245	< 0.01
Average (8 a 9) =	164.5000	6.5828	< 0.01

This behavior can also be seen by factorial analysis a x b (Table 8), where there were no significant differences on stomatal conductance between the schedules ($p = 0.2605$), but among the species ($p < 0.0001$). This test also shows that the Stomatal behavior is significantly influences for interaction between schedules and species ($p < 0.0001$).

Table 8: Factorial Analysis *(a x b)* for comparison of stomatal conductance (gs mmol H_2O / m^2s) in leaf tissues of nine plant species at three different times (08-09: 00 a.m., 11-12: 00 a.m. and 05-06: 00pm), Novo Lugar community, Santarém, Pará, Brazil.

Sources of Variation	
Treatments (hours)	2
Blocks (Specie)	8
Interaction (Specie x Hours)	16
P (Treatments)	0.2605
P (Blocks) =	< 0.0001
F (Interaction) =	7.0841
P (Interaction) =	< 0.0001

Conclusions

A variation in leaf stomatal conductance in all species throughout the day exists, and such variations produced based on the different patterns of physiological behavior of each species. Urubucaá (*Aristolachia trilobata)* showed the highest averages of stomatal conductance, thus could be consider a sensible specie in future water stress scenars.

For the other way, banana (*Musa sp.)* was more efficient in stomatal control, because it limited the water losses, decreasing stomatal conductance in higher DPV conditions. It concluded that the nine species useful for Borari indigenous people of Novo Lugar community has a different stomatal behavior from each other, since they respond differently to environment. The plant ecophysiology is good indicator for studies in indigenous communities, as a tool for understand the functioning of these species in face of current and future climate changes.

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