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# Influência da Luminosidade nos Atributos Funcionais em *Quesnelia quesneliana* (Brongn.) L.B.Sm.

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**Influence of Luminosity on Functional Attributes in *Quesnelia quesneliana* (Brongn.) L.B.Sm.**

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**Título resumido: Influence of Luminosity in *Quesnelia quesneliana* (Brongn.) L.B.Sm.**

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**ABSTRACT** – (Influence of Luminosity on Functional Attributes of *Quesnelia quesneliana* (Brongn.) L.B.Sm.). *Quesnelia quesneliana* is an endemic species from Brazil with restricted distribution in restinga areas and has been suffering from changes in its habitat. This study aimed to evaluate the influence of light on the morpho-anatomy and pigment content of *Q. quesneliana*. The samples were collected in the Liberdade neighborhood in São Mateus, Espírito Santo State, Brazil, which is impacted by anthropization. The influence of light was tested comparing individuals completely exposed to it and individuals under shade. For a morphobiometric analysis, 150 individuals were measured for each light condition, and for pigment determination, 10 leaves were used for each light condition. For anatomical analysis, samples were fixed in 50% FAA and transferred to 70 % ethanol solution after 48 hours. Cross sections were made on roots and stems, and transverse and paradermal sections on leaves. It was concluded that individuals exposed to light are smaller, with higher carotenoid content, while shaded individuals are larger, with more succulent and darker leaves due to greater accumulation of chlorophyll. Anatomically, the individual's structure is similar.

**Keywords:** Bromeliaceae, Bromelioideae, leaf anatomy, light condition, morphological attributes

**RESUMO** – (Influência da Luminosidade nos Atributos Funcionais em *Quesnelia quesneliana* (Brongn.) L.B.Sm.). *Quesnelia quesneliana* é endêmica do Brasil com distribuição restrita nas áreas de restinga e vem sofrendo com alterações no seu habitat. O trabalho objetivou avaliar a influência da luminosidade na morfoanatomia e conteúdo de pigmentos foliares de *Q. quesneliana*. As amostras foram coletadas no bairro Liberdade em São Mateus, Estado do Espírito Santo, Brasil, que sofre com ações antrópicas. A influência das condições de luminosidade foi testada comparando indivíduos completamente expostos à luminosidade e à sombra. Para as análises morfobiométricas foram mensurados 150 indivíduos por condição luminosa, e para a determinação de pigmentos, foram utilizadas 10 folhas por condição luminosa. Para a análise anatômica, as amostras foram armazenadas em FAA 50 para fixação e transferidas para etanol 50% após 48 horas. Foram realizadas secções transversais em raízes e caules, e secções transversais e paradérmicas em folhas. Conclui-se que os indivíduos expostos a luminosidade são menores, com maior teor de carotenoides, enquanto os indivíduos sombreados são maiores, com folhas mais suculentas e escuras devido ao maior acúmulo de clorofila. Anatomicamente, a estrutura dos indivíduos é similar.

**Palavras-chave:** anatomia foliar, atributos morfológicos, Bromeliaceae, Bromelioideae, condição luminosa

## Introduction

Light is essential for plant growth and development, and it constitutes of a key element for photosynthesis (Taiz & Zeiger 2017). Both excess and lack of light can cause damage to plants, which have developed different mechanisms to maximize the capture of light or minimize the effects of high luminosity (Ruberti *et al.* 2012).

Among the vegetative organs, the leaf is the most plastic since it is more exposed to environmental conditions, being able to respond differently to changes in the environment (Dickison 2000). Leaves from the same individual that develop in sunny environments tend to be smaller and thicker and have a higher stomatal density than leaves in shaded areas (Cutter 1987, Valladares & Niinemets 2008, Mendonça *et al.* 2020). Structurally, sun leaves have a thicker cuticle and greater abundance of trichomes, however, the most notable differences are in the mesophyll, which is thicker in sun leaves due to the increase in the palisade parenchyma layers (Dickison 2000).

In contrast, leaves which develop in shaded environments are thinner, with a higher pigment content and a more compact mesophyll due to the few layers of palisade parenchyma, in addition to abundant intercellular spaces in the spongy parenchyma. Furthermore, shade leaves may have specialized epidermal cells on the abaxial surface, which improve sunlight capture (Dickison 2000). Thus, studies on the morphoanatomical adaptations of species in response to environmental factors, such as light intensity, are fundamental for the comprehension of species biology, as well as their ecological relationships within the environment.

*Quesnelia quesneliana* (Brongn.) L.B.Sm. belongs to the Bromeliaceae family, being an endemic species of Brazil. The species is 40-170 cm tall, with an epiphytic or terrestrial habit. The rhizome is long and the roots are present in adult plants. The leaves are about 30-150 cm long, leathery, rosulate, with a thorny margin and terminal spines (Oliveira & Tardivo 2020). The species occurs in restinga areas, being often found as epiphytic, rupicolous or terrestrial and, according to Flora do Brasil (2020), its occurrence is confirmed in States of Espírito Santo and Rio de Janeiro, possibly occurring in Minas Gerais State too.

Due to its use as ornamental in landscape projects and interior decoration, *Q. quesneliana* has been undergoing extractive action, which may further compromise the perpetuation of local populations (Vieira 2006). In addition, the opening clearings in areas of restinga may result in habitat loss due to the high incidence of solar radiation, benefiting those with adaptations to high light intensity (Nascimento *et al.* 2008). This process can be harmful to species which germinate and develop in shaded areas (Valladares *et al.* 2016), consequently reducing local diversity.

Variations in morphoanatomical and physiological attributes may occur in plants growing in the same environment, although they are more evident in individuals from different habitats. Thus,

carrying out studies with plants in their natural environment is a challenge, since many factors such as water, light and temperature can not be isolated as in controlled experiments. However, they are extremely important for surveying ecological aspects.

Although *Q. quesneliana* occurs in open and shaded environments within the restinga, increased luminosity caused by anthropogenic and natural actions can generate structural changes, which may interfere in the species growth and development. In this context, the study of ecological anatomy is extremely important to highlight the adaptive strategies of species in response to changes in environmental conditions. Considering that *Q. quesneliana* occupies areas with different light conditions, and that the restinga is likely to suffer the impacts of environmental changes (Inague *et al.* 2021), due to the scarcity of anatomical studies with *Q. quesneliana*, especially ecological ones regarding light conditions, this study aimed to evaluate the influence of light condition on the morphoanatomy of *Q. quesneliana* vegetative organs.

### Material and methods

Individuals completely exposed to the sunlight and shade were collected in a restinga area in the Liberdade District (18° 45'034"S, 39° 45'455"W), located in the municipality of São Mateus, north of Espírito Santo State, Brazil. According to the climate classification proposed by Köppen, São Mateus region fits into the Aw type, characterized by a humid tropical climate with a dry winter and maximum rainfall in the summer. The average annual temperature is 24.2°C, and the average annual precipitation reaches values of 1311 mm, with October to April being the period of greatest precipitation (Nóbrega *et al.* 2008).

The fertile material was deposited at the Sames Herbarium, under the vouchers 1035 (sun plant) and 1038 (shade plant). The species was chosen due to its occurrence in the area under anthropic action, with the occurrence of individuals completely exposed to both sunlight and shade in the same area, allowing the comparison between such conditions on the species.

In order to compare the effects of luminosity in *Quesnelia*, 10 clumps completely exposed to sunlight and 10 completely shaded were selected. For each clump, five specimens were taken, totaling 50 individuals per light condition. For these individuals, the following parameters were evaluated: architecture of the rosette in terms of height; morphological aspect related to the color of the leaf blade; and diameter, in which two perpendicular measures were considered for each individual: an equatorial (rosette I) and a polar one (rosette II) with the aid of a tape measure. Roots and stems were classified according to the terminologies of Bell & Bryan (2008).

For the biometric analysis of the leaves, measurements were made on the three fully expanded ones from the periphery of the rosette in each of the analyzed rosettes, totalling 150 leaves per light

condition. The parameters evaluated were length and width of the sheath and blade, measured with the aid of a millimeter ruler. The measurement was made at the base of the sheath and in the median region of the leaf blade.

To obtain the succulence index, the formula proposed by Mantovani (1999) was adopted:  $SI = (MFM/DM)/FA$ , where MFM indicates maximum fresh mass, DM indicates dry mass and FA indicates foliar area. The Leaf Area (LA) and the Leaf Index (LI) were calculated using the equations  $LA = L \times W$  and  $LI = L/W$ , and in both, L corresponds to blade length and W to blade width. The sheath was excluded from calculations.

For pigments quantification, 10 leaves from each light condition were used, and each leaf was removed from a clump, totaling 20 leaves. The leaves were sectioned into small fragments in the median region and after the obtention of leaf mass, they were separated into 10 samples of 0.3 grams, each one corresponding to one leaf. Afterwards, the samples were stored in a refrigerator at 4 °C for a week. The cooled material was macerated with acetone and then filtered with filter paper into a 25 mL volumetric flask. This volume was completed with acetone, stirred and transferred to a capped test tube and kept on ice. The resulting filter samples were transferred to cuvettes and the readings were performed in a spectrophotometer (BEL Photonics 1105) at wavelengths of 710.0 nm (residues), 661.6 nm (chlorophyll *a*), 644.8 nm (chlorophyll *b*) and 470.0 nm (carotenoids). The pigments were quantified using the equations presented by Lichtenthaler (1987).

For the anatomical analysis, roots, stems and leaves were collected from five individuals completely exposed to light and five completely shaded. They were fixed in FAA (formaldehyde: glacial acetic acid: 50% ethyl alcohol, 2:1:18 V/V/V) modified from Johansen (1940) for 48h and transferred to 70% ethanol. Cross sections were made in the piliferous zone of developed roots, all with the same thickness and stage of development, with the aid of a razor blade and styrofoam. Cross sections of the internodal region of the stem and median region of the leaves, paradermic cuts of the median region of the adaxial and abaxial portions of the sheath and blade were also made with the aid of a razor blade and styrofoam. Samples were clarified with 25% sodium hypochlorite solution, stained with 0.5% alcian blue and 1% safranin (Luque *et al.* 1996), and mounted between lamina and coverslip with glycerinated gelatin (Kaiser 1880). The slides were analyzed and the images obtained in a photomicroscope Motic BA 210 with projection of micrometric scales.

For the biometric data analysis, descriptive statistic was used, calculating the standard deviation among the means obtained. The data was submitted to a normality test, analysis of variance (ANOVA) and Tukey's test, using the statistical software ASSISTAT 7.6 beta (Silva 2008).

## Results

Regardless of the luminous condition, individuals of *Q. quesneliana* were found forming clumps (figure 1 a-b).

The rosettes from the areas in full sunlight, when compared to those from shaded areas, show evident differences regarding the architectural traits. The plants totally exposed to sunlight are smaller in height ( $58.60 \pm 11.04$ ) and less green (figure 2 a-b), while the fully shaded plants are larger ( $66.68 \pm 04.98$ ) and greener (figure 2 c-d). The terminal spine is more evident in the sun condition (figure 2d). The sheath does not show differences in color considering the light conditions (figure 2e-f). The number of leaves and height of the rosette do not present significant statistical differences. Statistical tests show a significant difference considering the rosette diameters. Individuals exposed to the sun show, on average, smaller diameters than shaded individuals (table 1).

Blade length and sheath width present lower average values in plants exposed to the sunlight, when compared to those shaded (table 1). The data on succulence, leaf area and leaf index also show lower average values for leaves in the solar condition (table 1).

The leaves of individuals exposed to the sunlight are noticeably less green when compared to individuals in the shaded areas, which is related to chlorophyll content. The data shows that the levels of chlorophyll a and b are higher in shaded individuals, while the carotenoid content is higher in leaves completely exposed to sunlight (table 1).

Morphologically, the stem is subterranean of the rhizome type, sub-ligneous, with definite nodes and internodes (figure 3a). The roots are adventitious, underground, fasciculate, short and extremely thin (figure 3 b).

When compared, the vegetative organs present qualitatively similar anatomical features under different light conditions, with some differences described below for each organ.

The leaves of *Q. quesneliana* in both light conditions are hypostomatic. In frontal view, the epidermal cells showed straight and thick walls in both leaf faces. The stomata are tetracytic-like (figure 4a) and are arranged in parallel rows, interspersed with scales (figure 4b). The scales are present on both sides of the leaves and are also arranged in parallel rows following the longitudinal axis of the leaf (figure 4c). In frontal view, the scales showed irregular shape, being the central shield constituted by approximately ten rectangular cells. These central cells are surrounded by two sets of elongated cells of different sizes (figure 4d). The scales are inserted into the epidermis and are constituted by basal, pedicle and wing cells, with two pedicle cells in *Q. quesneliana*.

Cross sections of the leaf blade (figure 5a-b) showed a uniseriate epidermis with quadrangular cells covered by a cuticle, and stomata below the level of other epidermal cells (figure 5c). The lumen is lenticular in shape due to the thickening of the anticlinal and periclinal walls, as well as reduced

size in relation to other leaf cells. The mesophyll is homogeneous with collateral vascular bundles (Figures 5a-b) arranged in a single series, which alternate between bundles of larger and smaller caliber, and in some cases, the sclerenchymatic sheath surrounds the vascular bundle and extends to both mesophyll faces (figure 5d). An aquiferous parenchyma occurs adjacent to the hypodermis, present only on the adaxial face, composed of a chlorophyllated cells with irregular shape and thin walls (figure 5a-b). The chlorophyll parenchyma showed cells with thin walls and irregular shape, being interrupted on the abaxial face by aeration channels formed by stellate brachiform cells (Figure 5e), located between the vascular bundles and adjacent to the substomatal chamber (Figure 5a-c).

The subterranean stem showed uniseriate epidermis composed of elongated cells in the horizontal plane and with a thin layer of cuticle. The cortical region is constituted by homogeneous parenchyma with isodiametric cells (figure 6a), with dispersed idioblasts with straight-edged raphides (figure 6b), followed by randomly distributed collateral vascular bundles (figure 6c), with no pith delimitation.

The roots presented uniseriate epidermis composed of cells with irregular shapes and single-celled absorbent hairs (figure 7a-b). The external cortex is formed by parenchymatic tissue distributed in 3-4 layers of cells with thin walls (figure 7c-d). The median cortex is formed by sclerenchymatic tissue whose cells have a thick wall, distributed in 2-4 layers in the luminous condition and 2-3 layers of cells in the shadow condition. The internal cortex is formed by parenchymatic tissue distributed in 3-4 layers of cells with thin walls, with the cell spaces being more evident in the sunlight condition. The endodermis has thickened cell walls with U-shaped thickening, being compact and with no intercellular spaces (figure 4c-d). The vascular cylinder consists of pericycle, phloem and polyarch xylem, and the medulla is composed of isodiametric cells with thickened walls.

## Discussion

The biometric data regarding the number of leaves and plant height did not present significant differences when comparing both luminous conditions. This result corroborates with Mandai *et al.* (2008), who did not observe differences between the average height values in *Quesnelia arvensis* (Vell.) Mez under different light conditions. The smaller diameters for individuals of sunlight condition can be explained by the fact that plants submitted to high radiation have more imbricated leaves, resulting in a smaller diameter of the rosette (Voltolini & Santos 2011). Similar results were observed by Reinert *et al.* (2013), where the diameter of the rosette was less than half that observed in shade plants. The authors also comment that the architecture of the rosettes of plants exposed to the sunlight provides less light capture due to reduced leaf surface exposure (Reinert *et al.* 2013).

Leaf area is considered a highly plastic feature, and plants exposed to intense solar radiation tend to show a reduction in leaf area (Sarijeva *et al.* 2007), as observed in the present study. Our data corroborate the findings of Voltolini & Santos (2011) when studying variations in leaf morphoanatomy of *Aechmea lindenii* (E. Morren) Baker var. *lindenii*. In addition to the leaf area, the leaf index was also lower in plants exposed to sunlight compared to plants in shaded environments. Similar results were obtained with *Q. arvensis* under different light conditions within two restinga areas (Mandai *et al.* 2008), and with *Cryptanthus beuckeri* E. Morren cultivated in different light intensities under experimental conditions (Ribeiro & Aoyama 2017). These findings show that plant's exposure to solar radiation can inhibit leaf expansion as both leaf area and leaf index increase in shaded plants (Valladares & Niinemets 2008). Furthermore, the leaf reduction in plants exposed to intense solar radiation reduces water loss through evapotranspiration, being a strategy for conserving stored water (Boeger & Gluzezak 2006).

On the other hand, in shaded plants, it's often observed an increase in the height and length of the blade, as well as in the leaf area. According to Valladares & Niinemets (2008), the expansion of the leaf surface occurs because shade plants seek to maximize the interception of light rays, favoring the capture of photons and aiming to increase their photosynthetic capacity. The authors also point out that, although shade-tolerant species do not necessarily have higher photosynthetic rates compared to sun-tolerant species, they manage to reduce CO<sub>2</sub> loss due to lower respiratory rates.

Increased leaf succulence is usually associated to increased solar radiation. This has also been observed in Bromeliaceae (Cavallero *et al.* 2009, Cavallero *et al.* 2011) and other species occurring in the restinga (Melo Júnior & Boeger 2016). However, in *Q. quesneliana*, a higher index of succulence was observed in shaded leaves. The same could be verified for fresh and dry mass, which interferes directly in succulence, corroborating with Ribeiro & Aoyama (2017) who observed more succulent leaves of *Cryptanthus beuckeri* grown in a shaded area. According to Mantovani (1999), succulence is considered as the ability of plants to accumulate water per unit area of leaf. Thus, considering the higher values in the length and width of the sheath and limb, and the diameter of the rosette, shaded plants would be able to store and conserve a greater amount of water in their leaves compared to sun plants, which would explain the greater succulence.

In relation to pigment determination, chlorophyll a and b contents were higher in shaded plants, as already mentioned in the literature (Valladares & Niinemets 2008, Lennon *et al.* 2021). Chlorophyll contents are influenced by luminosity, therefore, its accumulation in shaded leaves is due to the lower available radiation (Valladares & Niinemets 2008), and the reduction of chlorophyll in leaves exposed to luminosity may be a result of photoinhibition (Lennon *et al.* 2021). In comparison, the carotenoid data was higher for the leaves exposed to sunlight since under strong radiation, there is an increase in the concentration of protective pigments in the chloroplast (Idris *et al.* 2019).

According to Siefermann-Harms (1987), carotenoids are responsible for collecting light energy, as well as protecting the photosynthetic apparatus against the harmful effects of light and oxygen.

The values of chlorophyll *a* plus chlorophyll *b* were higher for shade conditions, like the results observed by Reinert *et al.* (2013) on leaves of *Neoregelia cruenta* (R. Graham) L.B.Sm. This result highlights the strategy of shade plants concentrating more photosynthetic pigments in their leaves to compensate for the lower available radiation (Dousseau *et al.* 2007). According to Scalon *et al.* (2003), the increase in chlorophyll *b* in shaded leaves is an adaptive mechanism to the lower light intensity, since it captures the light energy of other wavelengths and transfers it to chlorophyll *a*, which acts in the photochemical reactions of photosynthesis.

The chlorophyll *a/b* ratio tends to decrease in shaded environments due to the greater increase in chlorophyll *b*, which is degraded more slowly in relation to chlorophyll *a* (Engel & Poggiani 1991). Therefore, the chlorophyll *a* and *b* ratio reflect the ability of plants to maximize light capture under conditions of greater shading (Dousseau *et al.* 2007), as photosynthetic rates are generally lower compared to plants that are in full sunlight. (Sarijeva *et al.* 2007). However, the values obtained in the present study for chlorophyll *a* and chlorophyll *b* ratio did not present a significant difference in both luminous conditions.

Anatomically, *Q. quesneliana* showed no structural differences regardless of the light condition. In Bromeliaceae, the presence of scales is commonly observed, considered a synapomorphy of the family (Ballego-Campos & Paiva 2018), and they are found predominantly in leaves. According to Ballego-Campos e Paiva (2018), the bromeliad scales are multicellular structures made up of basal cells, pedicle and shield. In the abaxial face their arrangement protects the stomata, which are tetracytic, being a standard type for the family (Proença & Sajo 2004, Krahl *et al.* 2013). The scales are also responsible for water and minerals absorption, and are also associated to reduction in transpiration, mechanical protection, and solar reflectance (Benzing 1976). Also, according to the authors, this structure is remarkable in this family, possessing taxonomic value since it differs among subfamilies (Oliveira *et al.* 2018, Silva *et al.* 2018).

The presence of stomata in only one leaf face, protected by epidermal depressions or scales, reduces plant transpiration and effective water loss (Larcher 2006). According to Brighigna *et al.* (1984), the aquiferous parenchyma retains water absorbed through the scales and protects the chlorophyll parenchyma against excessive solar radiation, which avoids water loss and favors photosynthesis.

On the roots, in the outer layer of the canopy, they can develop absorbent hairs, reported for other species of Bromeliaceae belonging to the subfamilies Bromelioideae, Pitcairnioideae and Tillandsioideae (Proença & Sajo 2008, Silva & Scatena 2011, Segecin & Scatena 2004). According to Peterson and Farquhar (1996), absorbent hairs are responsible for the absorption of water and

nutrients, demonstrating that such structures can expand the absorptive surface of plants (Pita & Menezes 2002).

In the stem, in both luminous conditions, idioblasts containing raphide crystals were observed. Calcium oxalate crystals play a role in the regulation of calcium in plant cells, having ecological importance both in the reflection of sunlight, as in the uniform distribution of light in plants in shaded places. Besides that, they can act secondarily, in the defense against herbivores (Franceschi 2001, Paiva 2021).

Changes in leaf anatomy in response to light are referred to in the literature as leaf sun and shade syndrome. According to Cutter (1987), sun leaves are generally thicker and differentiated in relation to shade leaves of the same species, in addition to higher trichome density and less leaf area. Yet according to the author, sun leaves tend to develop more layers of palisade parenchyma, resulting in greater leaf thickness together with the aquiferous parenchyma (Cutter 1987). Although the most expressive development of palisade and aquiferous parenchyma in sun leaves is reported in the literature, in the present study there were no differences in these tissues between plants from the two light conditions. This result indicates that the plastic responses are not always aligned, as morphological differences were observed, which were not reflected in the anatomy of the plants. In this context, it is important to have future studies analyzing the species for a longer time, in order to assess whether structural changes occur or whether the species plasticity is more expressive at the morphological level.

### **Conclusion**

It was concluded that luminosity significantly affects the diameter of the rosette, fresh and dry mass, length of the blade, sheath width and pigment content. Individuals completely exposed to sunlight are smaller and have higher leaves, while individuals completely shaded are larger, with darker and more succulent leaves.

*Q. quesneliana* has undergone changes with the increase in luminosity from sun to shadow, however, anatomically it presents a tissue arrangement that allows it to survive in both high and low light conditions. As previously mentioned, the importance of studies that monitor the species for longer periods throughout the year is highlighted, in order to verify if there will be any anatomical changes in response to light.

### **Conflicts of interest**

There is no conflict of interest.

## Author Contributions

**Letícia Elias:** Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

**Patrícia Denoni de Lima:** Contribution to data collection and analysis; Contribution to manuscript preparation.

**Gabriela de Souza Fontes:** Contribution to data collection and analysis; Contribution to manuscript preparation.

**Elisa Mitsuko Aoyama:** Contribution in the concept and design of the study; Contribution to critical revision, adding intellectual content.

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Figure 1. General aspect of *Quesnelia quesneliana* (Brongn.) L.B.Sm. in the restinga areas. a. Clump in sun environment. b. Clump in shade environment.



Figure 2. General aspect of the blade and sheath of *Quesnelia quesneliana* (Brongn.) L.B.Sm. a, b, e. Sun plants. c, d, f. Shade plants. a. Lighter coloring of the blade and marginal spines. b. Detail of the acute apex ending in a thorn less evident in the blade of sun plants. c. Darker color of the blade and marginal spines. d. Detail of the acute apex terminated in a more evident spine in the blade of shaded plants. e-f. Detail of sun and shade, respectively.

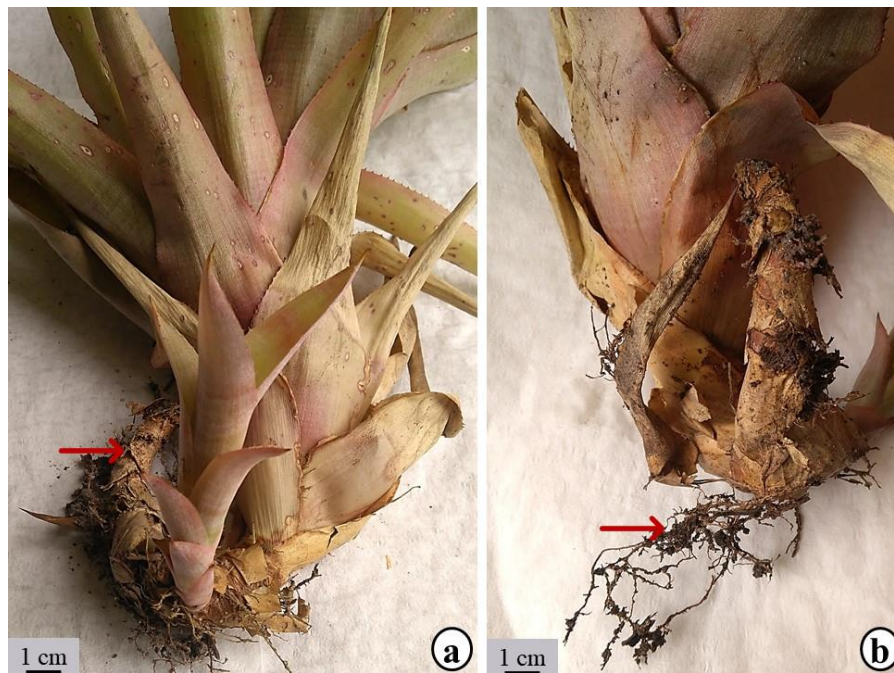


Figure 3. Aspect of stem and roots of *Quesnelia quesneliana* (Brongn.) L.B.Sm. in the sunny condition. a. Rhizome type stem. b. Detail of the adventitious roots (arrow).

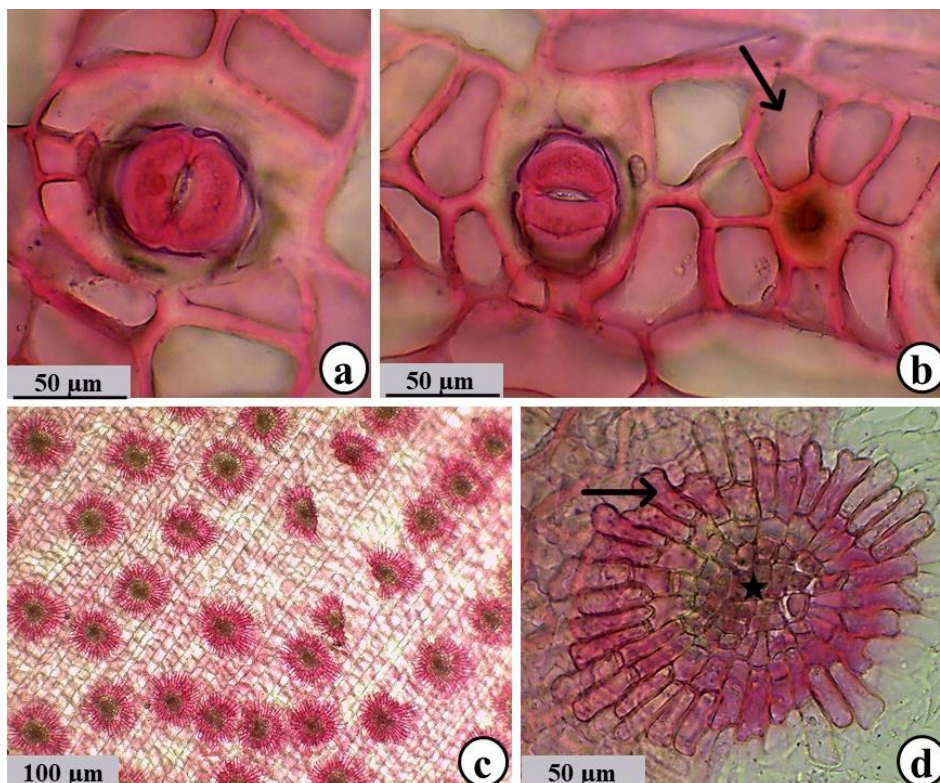


Figure 4. Paradermic sections of the median region of the leaf the *Quesnelia quesneliana* (Brongn.) L.B.Sm. in sun plants. Stained with 1% Safranin. a. Tetracytic stomata. b. Detail of the stomata interspersed with the scale (arrow). c. General aspect of the distribution of scales on the adaxial face of the sheath. d. Detail of the scale showing the central shield (star) and the wing cells (arrow).

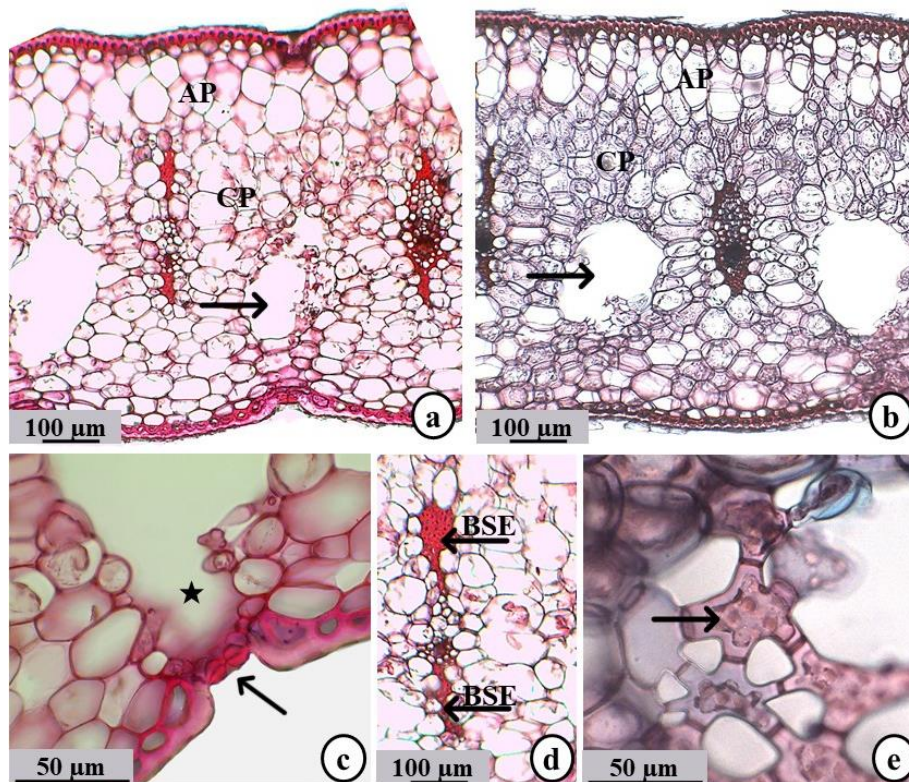


Figure 5. Cross sections of the leaf of *Quesnelia quesneliana* (Brongn.) L.B.Sm. a, c, d. Sun plants. Stained with 1% Safranin. b, e. Shade plants. Stained with 0,5% Alcian Blue and 1% Safranin. a, b. Dorsiventral mesophyll, consisting of the aquiferous parenchyma (AP), chlorophyll parenchyma (CP) and aeration channels (arrow). c. Stomata below the level of epidermal cells (arrow) and substomatal chamber (star). d. Detail of the sheath extension in the smaller caliber bundle (arrow). BSE: Bundle sheath extensions. (e). Detail of the star-shaped bractiform cells (arrow) in the aeration channel.

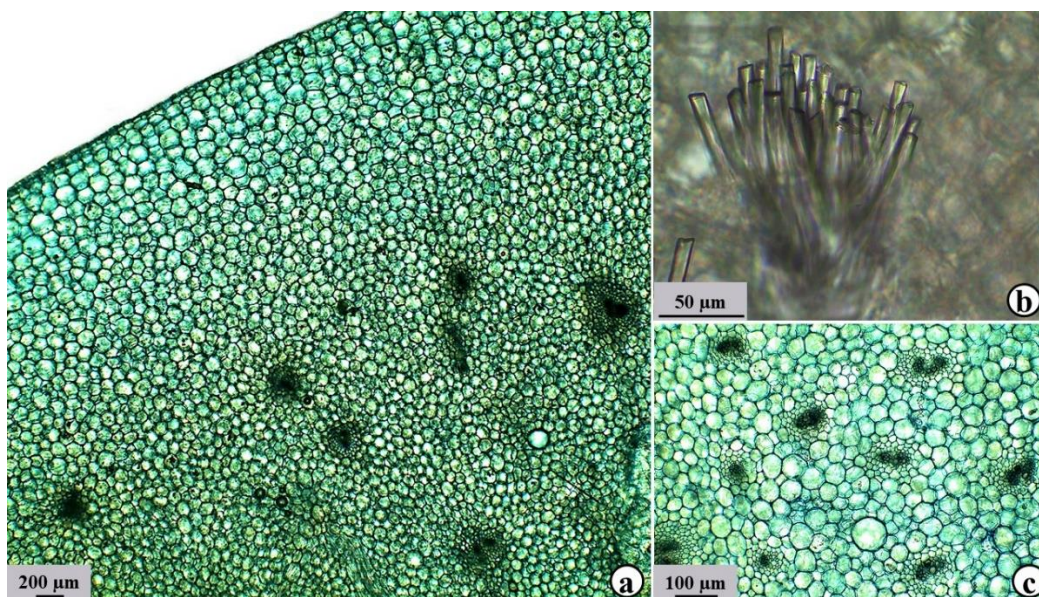


Figure 6. Cross sections of the stem of *Quesnelia quesneliana* (Brongn.) L.B.Sm. in sun plants. Stained with 0,5% Alcian Blue. a. General aspect. b. Raphide type crystals. Colorless image. c. Detail of vascular bundles with random distribution in the parenchyma.

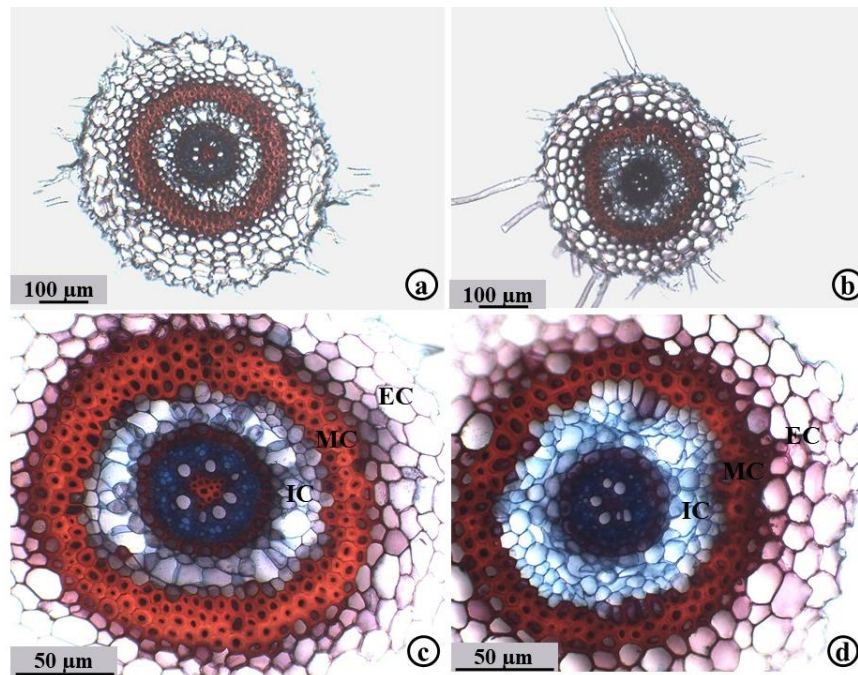


Figure 7. Cross sections of the root of *Quesnelia quesneliana* (Brongn.) L.B.Sm. Stained with 0,5% Alcian Blue and 1% Safranin. a, c. Sun plants. b, d. Shade plants. a, b. General aspect showing the absorbent hair. c, d. Details of the external cortex (EC), median cortex (MC), internal cortex (IC) and vascular cylinder.

Table 1. Biometry and pigment quantification of *Quesnelia quesneliana* (Brongn.) L.B.Sm. exposed to different light conditions.

Parameters	Condition	
	Sun	Shade
Number of leaves	43,00 ± 10,02 a	39,60 ± 04,87 a
Plant height (cm)	58,60 ± 11,04 a	66,68 ± 04,98 a
Diameter of the rosette I (cm)	45,60 ± 10,76 b	59,30 ± 07,00 a
Diameter of the rosette II (cm)	47,80 ± 06,66 b	57,26 ± 04,35 a
Blade length (cm)	23,66 ± 03,19 b	28,38 ± 01,59 a
Blade width (cm)	,16 ± 00,26 a	,08 ± 00,30 a
Sheath length (cm)	12,66 ± 01,18 a	13,19 ± 00,37 a
Sheath width (cm)	,93 ± 00,39 b	,24 ± 00,41 a
Fresh mass (g)	14,50 ± 3,55 b	17,31 ± 3,98 a
Dry mass (g)	2,18 ± 0,66 b	2,70 ± 0,75 a
Succulence (g/cm <sup>2</sup> )	1,20 ± 03,90	2,38 ± 06,13
Leaf area (cm <sup>2</sup> )	116,25 ± 26,70	138,65 ± 36,94
Foliar index	5,78 ± 04,69	6,99 ± 01,95
Chlorophyll <i>a</i>	51,61 ± 50,80 b	139,45 ± 85,70 a
Chlorophyll <i>b</i>	16,72 ± 22,92 b	64,08 ± 40,35 a
Carotenoids	,85 ± 0,71 b	,76 ± 2,94 a
Sum of Chlorophyll <i>a</i> + Chlorophyll <i>b</i>	1,53 ± 0,90 b	4,77 ± 0,65 a
Chlorophyll <i>a</i> / Chlorophyll <i>b</i> Ratio	2,95 ± 3,5 a	2,35 ± 0,76 a

Means followed by the same letter do not differ significantly by the Tukey's test (significance level: 0.05). Different letters indicate differences of statistical significance between means ( $p < 0.05$ ). \*same letters: no statistically significant differences ( $p \geq 0.05$ ).

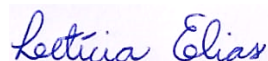
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