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FROM NATURE TO BUILDINGS: A BIOMIMETIC APPROACH AS ALTERNATIVE AGAINST STRUCTURES' HUMIDITY ISSUES IN JIJEL – ALGERIA

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Purpose. This study aims to explore the plants' potential to adjust to humid climates and understand their acclimation processes to inspire building designs and develop moisture-resistant building materials. It's based on the top-down biomimetic approach and proposes a method for applying biological processes to architectural concepts, referring to the anatomical diagnoses of moisture-resistant plants.
Results. The study revealed that mimicking the hierarchical structuring observed in leaf venation patterns significantly improved the mechanical strength and flexibility of the biomimetic materials. The results indicated that plants had evolved several morphological and physiological adaptations and validated the importance of considering both the cuticle and stomata as essential adaptive factors in developing a biomimetic process. Plant adaptation mechanisms led to a focus on porosity, external textures, hydrophobic additives, and multilayer structures of building materials to produce compositions suitable for humid climates inspired by these principles.
Scientific novelty. This research contributes to our understanding of how plants adapt to high humidity levels and underlines the importance of adopting the principles developed by biological systems to survive and cope with changing conditions.
Practical value. This study opens insights for more resilient bio-inspired architecture that responds adaptively to humid climatic environments and highlights the significance of creating suitable building materials for different climates and those adapted for climate change.
Key words: adaptation, biomimicry, building material, humidity, plants.

Introduction. Propelled by a fast population increase, the 20th century saw an unprecedented global surge in urbanisation. Until the middle of the 20th century, only 10 % of the worldwide population lived in cities; 56 % of the population today is urban, and by 2050, projected to reach 68 % [1]. This quick urban growth has brought its own challenges, the most urgent of which is climate change. Its environmental impacts are felt across ecosystems and human communities, presenting the most pressing threat to our planet that requires our attention. The increase in temperatures is one important effect of climate change, leading to changes in rainfall patterns and rising humidity levels in many regions of the world, including Jijel in Algeria. Recent research [2] conducted by experts at Columbia University in the United States has designated humidity as a contributing factor. Indeed, increasing humidity does exacerbate the effects of climate change; as released in a Science Advances study, the occurrence and strength of humidity waves doubled in frequency and severity between 1979 and 2017 [3]. This increased humidity effect first appears on buildings. It is not only a matter of appearance; actually, it can create significant challenges for the buildings, impacting their durability and the comfort of occupants, as well as an increase in energy consumption and potential health risks for residents [4]. According to the National Agency for Promotion and Rationalization of Energy Use (APRUE), Algeria's construction industry is responsible for 45.7 % of energy consumption and contributes up to 30 % of the world's annual greenhouse gas emissions [5]. As a major energy consumer, it is therefore crucial for this sector to develop technical solutions adapted to current climatic conditions [6]. Currently, we have moved from denial to acceptance of the truth of climate change. Aiming to create living spaces adapted to local climatic conditions, climate is an unavoidable environmental factor. It is at the heart of the dialogue between architecture and its environment. The human will to overcome the climate is a form of flourishing and development, expressed through its architecture specific to a particular climatic zone [7]. Confronted with the magnitude of the challenges, the traditional methods of humidity management, often energy-intensive and costly, struggle to respond effectively to these challenges. The necessity for adaptation and resilient solutions has become increasingly urgent [8].

In this context, biomimicry – learning from nature's proven solutions [9] – emerges as an approach for adapting buildings to climates. Adaptation is the process by which an organism develops and improves over generations its ability to survive in its natural environment [10]. Observing nature reveals that it is the only engineer capable of producing without recourse to fossil fuels, as stated in an article published by Terra Eco in OBS [11]. Living organisms, particularly plants, have in fact evolved a myriad of adaptations to thrive in different conditions by following an original logic in harmony with their environment. When confronted with climate change, some organisms adapt by migrating to more favorable contexts, while others develop defenses by modifying their morphology, physiology, or behavior [12]. Biological systems are perfectly structured and interconnected, which allows them to function in an efficient and coordinated manner [13]. Understanding these adaptive properties may inspire innovative design principles and strategies for creating buildings that interact harmoniously with their environment and regulate humidity passively and effectively.

Review of literature. Innovation Inspired by Nature refers to the act of imitating nature's processes and mechanisms to address human challenges. The method aims to find sustainable solutions by comprehending the fundamental principles and functions that control biological systems [14]. In architecture, this concept involves examining the adaptive strategies of organisms that flourish in a specific environment and subsequently incorporating these concepts into the design of buildings [15]. Biomimetic architecture is increasingly recognized for its ability to address climate change concerns, especially in humid climates. The Biomimicry Europa Association, created in 2006, proposed three levels of inspiration [16]. The organism Level corresponds to shape or surface biomimicry and focuses on mimicking the organisms' adaptations; it has been used in the Namibian Steno Cara created by Matthew Parkers of KSS Architects, which was a source of inspiration for designing the Hydrological Center at the University of Namibia [17]. The behavior Level, as its name indicates, involves emulating the behaviors of organisms; as in the Termite Mounds, the architect Mick Pearce mimicked the complex network of tunnels and chimneys seen in termite mounds to create natural ventilation systems in structures [18]. The ecosystem Level refers to the ultimate biomimetic level, where imitation occurs at the scale of entire ecosystems. It aims to replicate the relationships and interactions within ecosystems. The town of Kalundborg in Denmark [19], as the first example of industrial symbiosis, is a perfect illustration of this level.

Among the discoveries derived from the literature are the following:

1. Biomimetic Building Facades: a study has demonstrated the ability to reduce energy consumption in various building typologies and temperature zones [20]. The study experimented to evaluate the effectiveness of a computational model that simulates a biomimetic facade design inspired by animal fur and blood circulation. The findings demonstrated that the biomimetic facade has the potential to decrease energy usage across various architectural applications, particularly in residential elderly care, where a remarkable reduction of 67.1 % was observed.

2. Research has been carried out on the creation of adaptive building facades utilizing novel materials inspired by the biomimetic approach [21]. These materials can alter their arrangement and adjust to an external stimulus naturally and passively without the need for complex energy systems. By integrating these biomimetic principles into the component's definition, it is possible to enhance the design of sustainable architectural systems that can adapt the façade to varying external climatic conditions.

3. Sustainable Design and Biomimetic Architecture [22]: the topic of biomimetic architecture places a significant emphasis on the interplay between biology, environmental science, and sustainable design. The objective is to utilize energy-efficient and passive climate control mechanisms. Biomimicry has been assessed for its capacity to adapt to climate change in the constructed environment

4. Climate Change and Biomimicry [23]: the study piloted a comprehensive literature analysis on biomimicry and its contributions to addressing climate change through mitigation and adaptation.

These studies imply that in humid climates, biomimetic architecture can provide creative and long lasting architectural design solutions. This led us to adopt the following questions, and we endeavored to answer them through this work.

Q1. Would the bioinspiration approach be a viable option to adapt buildings to local climatic conditions, specifically increased humidity?

Q2. What are the specific adaptations of plants to the humid climate in Jijel?

Q3. Could design concepts for moisture-resistant building envelopes be generated based on the adaptive strategies of living organisms, and how can these adaptations be translated into architectural design principles for humidity regulation?

This research paper examines plants' specific adaptations to moisture and provides a methodology for transferring natural processes into construction principles. By using a biomimetic approach, we enhance interior comfort and the long-term resilience of buildings. Consequently, this article highlights the potential of biomimicry as a source of inspiration for architectural solutions adapted to high humidity levels. The objective is not to reproduce a natural control and decision-making system but rather to comprehend the mechanisms by which species acclimate to humidity.

Materials and methods. This section explains the research methodology we followed to answer the questions posed above. The selection of a suitable methodology relies on the context and objectives of the research study. This study is based on the Top-Down biomimetic approach (Figure 1) [24], according to the three main phases of the bioinspiration model (Scoping phase, research phase, and implementation phase) proposed by Sommese et al. in 2022 [25].

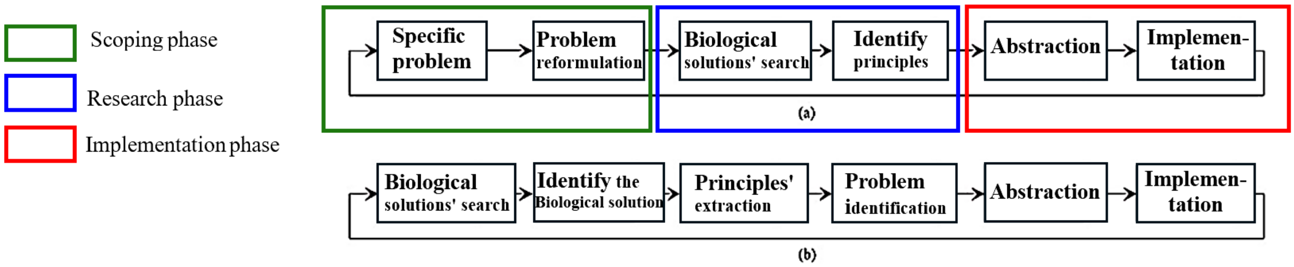


Figure 1. Biomimetic approach methods

Source: Helms et al., 2009.

This model provides a rigorous structure for using biomimicry in building design. Initially, we identified the problem at hand, which is the elevated humidity levels and their detrimental impact on buildings. Additionally, the study region was specified to have a clear and specific framework thereafter. Conduct a search for solutions inside ecosystems. Choosing the suitable biological model for our specific objective. In order to confirm that the chosen species are in line with our primary goal, a microscopic examination was conducted to discover the strategies and adjustments employed by the organism. Technical solutions proposed based on the biological model. Modification of solutions to fit the specific architectural environment.

Study zone. The study zone's spatial delineation was defined by considering several factors, including the suitable geographic position, the humid environment, the height, the amount of sunshine, and the external layout. Given that this research relies on living organisms as a source of inspiration, Jijel (Figure 2) represents one of the best options for obtaining examples and references in Algeria. Its advantageous position between the sea and the mountains favored a diverse range of plant and animal species [26]. Furthermore, as seen in (Figure 3) [27], the perceived humidity levels in this city show various periods of comfort and discomfort throughout the year.

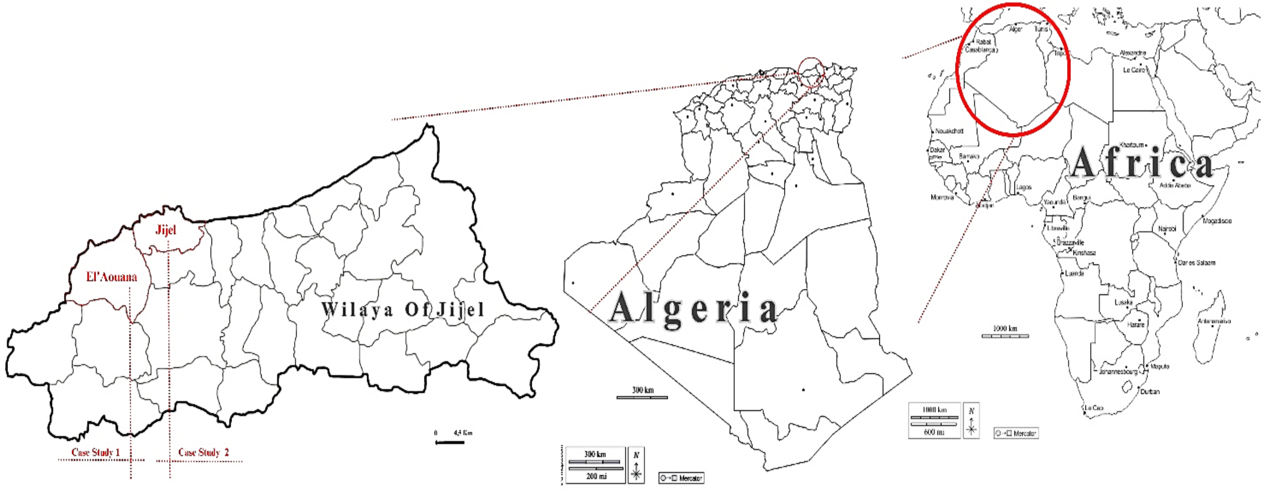


Figure 2. Study zone

Source: built by the authors, 2022.

The graph below (Figure 3) shows that the most humid period of the year in Jijel extends over 4 to 5 months. There is a clear peak in humidity during the summer months, reaching a maximum of 82 % in August, which negatively affects people’s comfort as well as buildings. This annual cycle highlights the impact of humidity on human comfort and underscores the importance of understanding local climate patterns for optimizing building design and ensuring well-being.

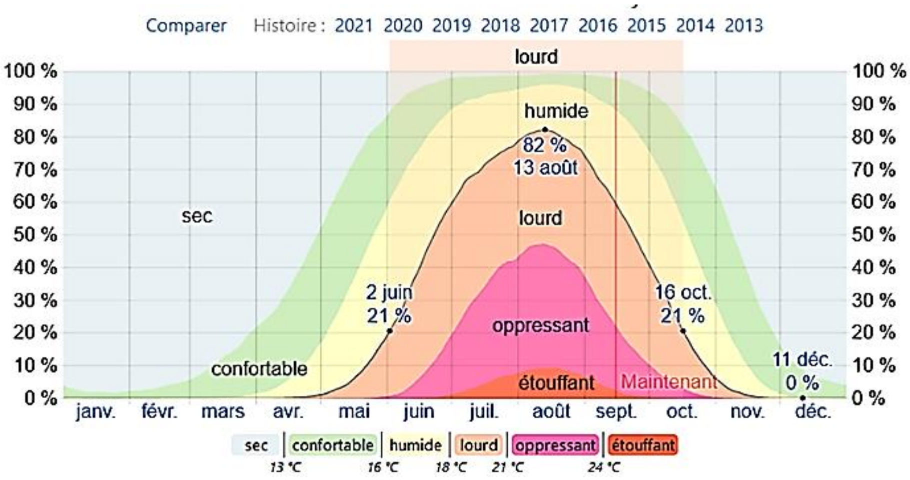


Figure 3. Comfort/Humidity in Jijel

Source: Weather-Spark, 2022.

Materials. Unique traits inherent to each plant facilitate their adaptation to specific environmental circumstances [28]. To select a suitable biological model for our requirements, interviews were conducted with experts in the field affiliated with the TAZA National Park and the National Forest Research Institute (INRF) / regional station. Furthermore, overlays of the main species inventories within the research zone were formulated to identify plants that have withstood climatic fluctuations and high humidity levels. The plants shown in the figure below (Figure 4) were chosen due to their varied moisture adaptation abilities, enabling the examination of a broad range of adaptation strategies. The leaves of pre-selected plants from the humid climate research area represented the plant materials.


Plane. Fig. Myrtle. Oliver. Fern. High ash. Araucaria. Jacaranda.

Figure 4. Plants material

Source: authors' research, 2022.

Since biomimicry does not have its own distinctive "varietal determination method", we relied on the traditional methodology [29], which is based on:

- *Morphological Examination*: examining the plant's outward features, such as its leaves, stems, flowers, fruits, and general growth patterns. The use of botanical keys ensured the accurate identification of the species. For this step, Plants exhibiting adaptation to increased humidity were selected and collected, and descriptive profiles were compiled for the identified biological models.
- *Anatomical Analysis* entails examining a plant's interior anatomy to detect and uncover adaptations pertinent to the study of biomimicry. Microscopy techniques are commonly used for this study.

1. Sample collection: plant sample collection is fundamental for achieving successful biomimetic investigations. To accomplish this, the subsequent procedures were adhered to:

- *Documentation:* record detailed information about each sample, including date, location, species, and any relevant observations about the plant and its environment.
- *Collection*: random leaf sampling was carried out using appropriate equipment during the peak humidity period, from June to October, to explore possible adaptations of plant species to it. Collect enough samples to offer representative data and allow the analysis duplication.
- *Sample Integrity:* fresh plant material was collected and carefully treated to minimize any harm to the plant tissues, hence maintaining their overall structure and integrity.
- Each sample consists of a pair of leaves from the same tree: one fully mature leaf (F.A) and one younger, secondary leaf (F.B). These leaves were selected from various tree canopy heights to allow for potential variations in microclimatic conditions.
- Each plant specimen's adaxial and abaxial leaf surfaces were evaluated. Two sections were obtained from each surface: one from the leaf's apex (P.1) and another near the leaf axis (P.2).
- *Storage and Transportation:* to prevent degradation, we kept and moved

samples in appropriate circumstances.

This extensive sample technique [30] was used to capture any potential differences in the structural and functional adaptations among various leaf ages, canopy locations, and leaf surfaces.

2. *Sample preparation*: the process of microscopic examination [31] encompassed:

- *Sanitization*: the workspace and equipment were cleansed with ethanol.
- *Dust Removal:* the leaves were dusted and maintained at a cool temperature.
- *Photographing:* to compute the foliar surface area, leaves were photographed
- *Mounting:* specimens were affixed on a slide and overlaid with a coverslip (Figure 5A).
- *Sectioning:* if epidermis is thick for observation, it is rubbed to procure thin sections (Figure 5B).
- All focusing operations were executed at both x4 and x10 magnifications, and each observation was documented photographically (refer to Figure 5C).

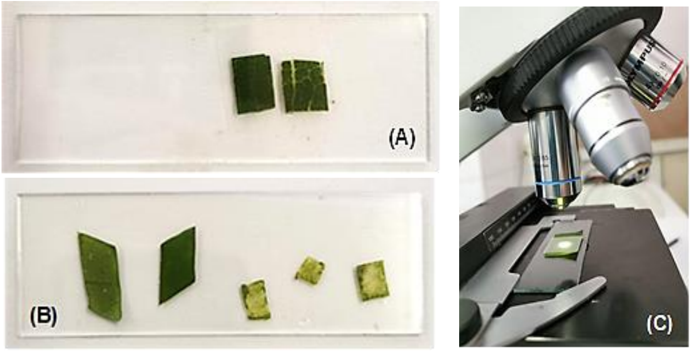


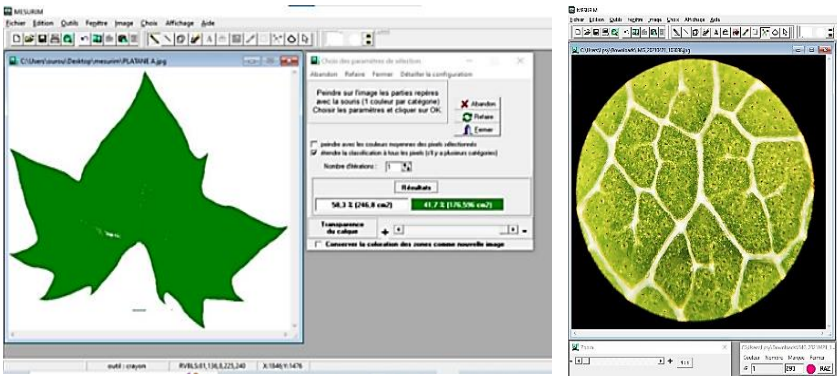
Figure 5. Slide mounting

Source: authors' research, 2022.

3. *Stomatal density:* a plant's stomatal density refers to the number of stomata present in a unit area [32]. The mean leaf area (Figure 6A) and stomata's number (Figure 6B) for each specimen were determined by MESURIM Pro software.

- Field of views D: x4: 5 mm; D: x10: 2 mm
- Microscopic area A = $(D^2/4) \times \pi$

At x4: $A = (5^2/4) \times 3.14 = 19.625$ mm². At x10: $A = (2^2/4) \times 3.14 = 3.14$ mm².



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58,3 % (246,8 cm2)

41,7 % (176,596 cm2)

A B

Figure 6. Leaf area / Stomata on Mesurim

Source: authors' research, 2022.

Results and discussion.

1. Morphological adaptation. The morphological analysis of the selected plants revealed variations in leaf persistence, size, and texture, highlighting a diverse array of adaptive traits, as outlined in Table 1.

Table 1

Plants' morphological adaptations

Plants' Leaf		Plants	Adaptation
Persistence	- Evergreen	- Myrtle, Olive	- Reduce transpiration / Resist to humidity
	- Deciduous	- Araucaria	- Conserve water and Energy
	- Hybrid	- High-ash, Fig, Plane Fern, Jacaranda	
Size & Shape	- Needles	- Araucaria.	- Reduce water loss
	- Small	- Olive, Myrtle, High ash.	- Limit evaporation / Prevent fungal issues
	- Large	- Plane & Fig tree	- Optimize light capture
	- Elongated	- Fern, Jacaranda	- Drainage structure
Texture	- Smooth	- Araucaria, Plane	- Reduce water
	- Multilayer	- Fern	- Regulate water quantity
	- Hairy	- Fig, Jacaranda	- Microclimates' creation
	- Hydrophobic	- Olive, Myrtle	- Avoid water stagnation

Source: authors' research, 2022.

The morphological examinations of the chosen plants revealed variations in leaf persistence, size, and texture, providing a wide range of adaptations. Where we distinguished:

- Evergreen plants, that demonstrated an adaptation strategy to steady environmental conditions;
- Deciduous plants, such as fig trees, to conserve water and energy during unfavorable periods;
- Hybrids, like fern and jacaranda, exhibit intermediate features by integrating aspects of both evergreen and deciduous strategies.

The leaf size also demonstrates significant variation. For instance, fine needles, as observed in Araucaria, are an adaptation that reduces water loss through transpiration while maximizing light absorption. On the other hand, larger leaves of up to 25 cm, as in plane trees optimizes light capture in potentially shaded environments.

Our observations indicate that the plant species that exhibit the highest tolerance to excessive humidity possess distinct characteristics tailored to this climate:

- Certain leaves, such as Araucaria' and Fern' possess a smooth surface with a thick cuticle and a drainage structure to channel water and prevent stagnation.
- Some leaves, like those of fig trees, myrtle (Figure 7A), and ash trees (Figure 7B), are occasionally coated with a liquid substance.
- Other leaves, such as jacaranda, have finely hairy upper surfaces or on the undersides, like Fig tree leaves (Figure 8).

These morphological adaptations equip these plants with enhanced survival capabilities in humid environments, thereby mitigating the detrimental impacts of surplus moisture on their structural and functional integrity.

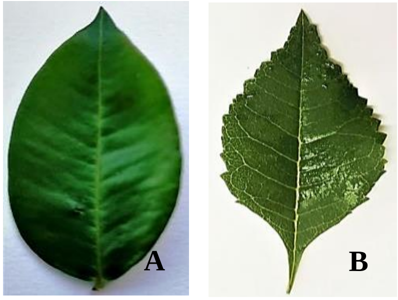

Figure 7. Myrtle & Ash tree's leaf

Magnification x4 Magnification x10

Figure 8. Jacaranda specimen on microscope

Source: authors' research, 2022.

2. Physiological adaptation. In terms of physiological adaptation, small orifices were observed on the undersides of the samples (less exposed surface), with varying densities among the different plants. These structures, known as stomata, play a crucial role in plant physiology by controlling transpiration and facilitating the flow of gases within the leaves [33]. The results showed that they display variability in their form, size, density, and distribution:

- Regarding Araucarias (Figure 9A), the stomata were aligned along the leaf's longitudinal axis and possessed an elongated, slender form.
- The stomata on Olive leaves were round and deeper, while those on High-ash leaves were oval, and those on Fig leaves (Figure 9B) were more widely distributed across the leaf surface.
- The stomata were present on both surfaces of the Plane and Jacaranda leaves (Figure 9C). Both can regulate the aperture of their stomata according to variations in temperature, light, and humidity.
- The stomata of Fig. and Jacaranda were larger than those of Plane trees Figure 9D and ferns.

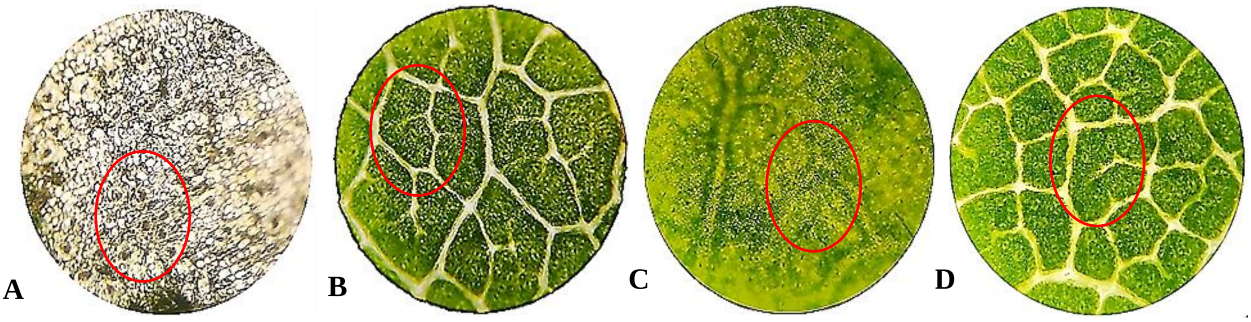

Figure 9. Plant material on microscope

Source: authors' research, 2022.

The Tables below and corresponding bar charts provide a comparative analysis of the stomatal density of the studied plants, considering two levels of microscopic magnification (x4 and x10) and two sampling locations on the leaf (P.1 and P.2).

Table 2

Number of stomata on leaf A

Plants	x4		x10	
	P.1	P.2	P.1	P.2
Araucaria	1295	2591	177	384
Fig tree	3493	5279	519	805
Fern	1904	3984	275	450
Ash tree	589	942	74	131
Jacaranda	1864	2630	268	359
Myrtle	353	510	51	76
Olivier	1747	3807	259	589
Plane	6260	8478	912	1276

Source: authors' research, 2022.

Table 3

Number of stomata on leaf B

Plants	x4		x10	
	P.1	P.2	P.1	P.2
Araucaria	726	1806	78	249
Fig tree	2002	3670	235	517
Fern	1040	2375	84	312
Ash tree	491	667	53	87
Jacaranda	1178	1452	139	192
Myrtle	236	412	21	46
Olivier	962	1197	114	156
Plane	4062	5279	610	805

Source: authors' research, 2022.

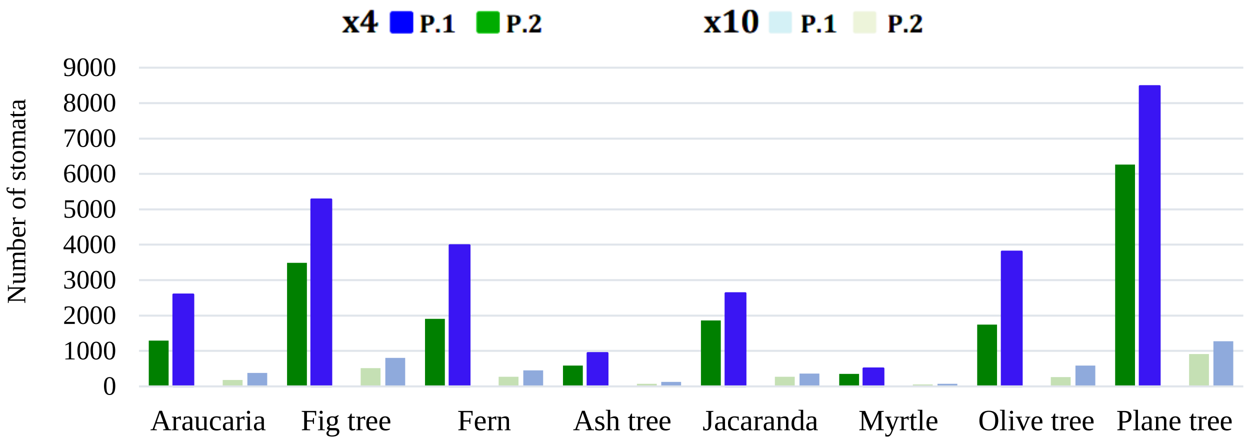

Figure 10. Stomata on leaf A

Source: authors' research, 2022.

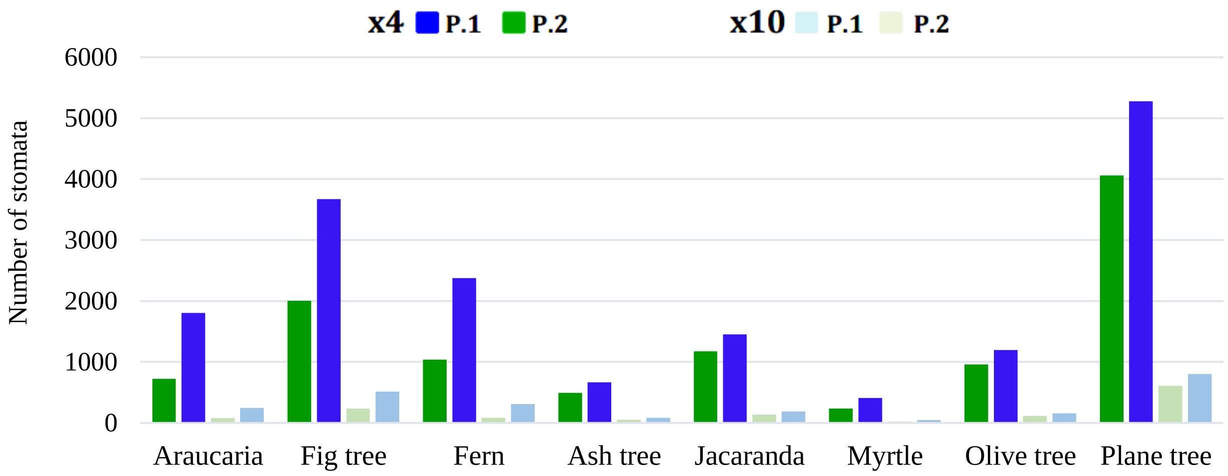

Figure 11. Stomata on leaf B

Source: authors' research, 2022.

The data reveals pieces of information on the stomatal distribution and potential implications for plant physiology and adaptation. The findings show that these plants have an average higher number of stomates than those suitable for arid climates [34].

These our observations:

- *Magnification Impact:* Tables 2 and 3 demonstrate that stomatal counts are higher with x4 magnification compared to x10 across all species and sampling sites.

- *Inter-species Variation:* at both magnification levels, significant differences in stomatal densities were observed among the plant species. This indicates inherent variability in leaf morphology, gas exchange mechanisms, and potential adaptations to humid environments. Among the specimens analysed.

- The Plane tree stands out with the highest stomatal counts at both magnifications and sampling locations (see Figure 10, 11). This species, which is resilient to urban conditions, is also recognized as a depolluting tree, absorbing 80 % of water from atmospheric humidity. This characteristic validates its widespread use as a decorative tree in city streets and urban locales.

- The velvety texture of the fig helps to capture moisture and make it accessible to the stomata while simultaneously offering protection.

- In the most well-known Mediterranean species, the Olive tree, the stomata are recessed and protected by umbrella-like hairs, reducing water loss by encouraging raw sap flow. This lower count, compared to the Plane tree, is attributed to the unique composition of its leaves, which possess a thicker cuticle and a cutinized upper epidermis that captures solar energy and slows evaporation.

- Myrtle, one of the species studied, represents the lowest stomatal count. However, its leaves are leathery and glossy, with a firm and thick cuticle. This unique combination of features suggests that Myrtle has developed alternative strategies to balance its water needs, a finding that adds depth to our understanding of plant adaptation.

- *Sampling Location Effect*: this observation revealed a significant variation in the stomatal count within identical species, contingent upon the following factors:

- Leaves: Specimens designated (F.A), which were larger, had a higher quantity of Stomates compared to the (F.B) samples.

- Position on the leaf: the plants' leaves are hypostomatic (high density on the lower surface). The data shows an interesting pattern: stomatal density is larger in P.2 samples (near the leaf axis) than in P.1 samples (leaf tip). This implies a possible disparity in the stomata distribution along the leaf's surface, which might be affected by growth related or environmental variables.

- *Adaptive Significance:* differences in photosynthetic processes and environmental adaptations are the primary factors accounting for plants' stomatal density variability. Plant species with high stomatal density tend to have higher transpiration rates and increased photosynthetic capacity, whereas species with low stomatal density have evolved to favor water conservation.

In the Table 4, we resume the adaptation mechanisms developed by the examined plant species. These diverse strategies aim to regulate the balance between ambient humidity and evaporation rates, allowing plants to adapt more effectively to environmental fluctuations while reducing their direct exposure to moisture, thus safeguarding them against dehydration.

Table 4

Plants' adaptation mechanisms

Plants	Morphological mechanisms								Physiological mechanisms	
	Large Leaf	Reduce Leaf	Thin Cuticle	Thick Cuticle	Hairy Surface	Hydrophobic Substance	Multi-layer	Drainage Structure	High stomatal density	Low stomatal density
Araucaria		• x		•					• x	
Fern	• x		•				• x	• x	• x	
Fig	• x		•		• x	• x			• x	
High ash		• x	•							• x
Jacaranda	• x		•		• x			• x	• x	
Myrtle		•		• x		• x				• x
Olivier		•		• x		• x			• x	
Plane	• x		•						• x	
x	- Efficient gas exchange; - Light absorption; - Remove surplus water		- Reduce evaporation; - Limit fungal diseases		- Microclimate creation; - Reduce transpira-tion	- Prevent water stagnation; - Reduce fungal infections risk	- Ensure transpiration; - Remove excess water; - Regulate water quantity		- Facilitate gas exchange and transpira-tion	- Reduce evaporation
	Adaptations to humid climate									

Source: authors' research, 2022.

3. *Stomatal density*. Derived from the data in Table 5, the histogram depicted in Figure 12 provides a dual representation of the correlation between leaf surface area and stomatal density. The changes seen in theses parameters highlight the complex interplay between morphological and physiological factors in shaping plant response to humidity.

Table 5

Stomatal density / leaf area

Plants	Stomatal density, mm²		Leaf, area cm²	
	F. A	F. B	F. A	F. B
Araucaria	132	92	65	30
Fig tree	269	187	350	240
Fern	203	121	89	64
Ash tree	48	34	14	7,3
Jacaranda	134	74	127	83
Myrtle	26	21	10	6,6
Olive tree	194	61	12	7,5
Plane tree	432	269	225	176

Source: authors' research, 2022.

Plants have been stratified into categories based on their stomatal density:

- *Positive correlation with high density*: including fig and plane leaves enhances efficient gas exchange, thereby increasing photosynthetic capacity. Furthermore, facilitates higher transpiration rates, prevents waterlogging, and supports the maintenance of optimal water balance in humid environments.

- *Average correlation with moderate density*: this category includes Ferns, Jacaranda, and Araucaria, where their large leaves correspond to lower stomatal density. This implies the possibility of employing alternate approaches to regulate transpiration and maintain equilibrium with the ambient humidity, such as reducing the number of stomata while increasing their size, as in Araucaria, or developing specific leaf structures that increase diffusion, as in the hairy surfaces of Jacaranda, to optimize gas exchange and water balance in humid environments.
- *Low density:* myrtle and Ash tree leaves had a reduced number of stomates but also a decreased surface area. However, this suggests that factors other than leaf size, such as thick cuticles or the substances they produce on the surface, could play a more important role in minimizing evaporation and water loss while maintaining sufficient gas exchange for photosynthesis.
- *Conversely,* we noticed a reverse correlation in the Olivier, wherein stomatal density increased but leaf area decreased. In terms of adaptation, its stomata possess a deeper structure and are protected by hairlike umbrellas, while its cuticle is thicker. These features serve to minimize water loss through evaporation and facilitate the exchange of gases.

These classifications highlight the ability of plants to adapt and offer valuable knowledge about the various methods used to improve gas flow and control moisture levels in humid environments.

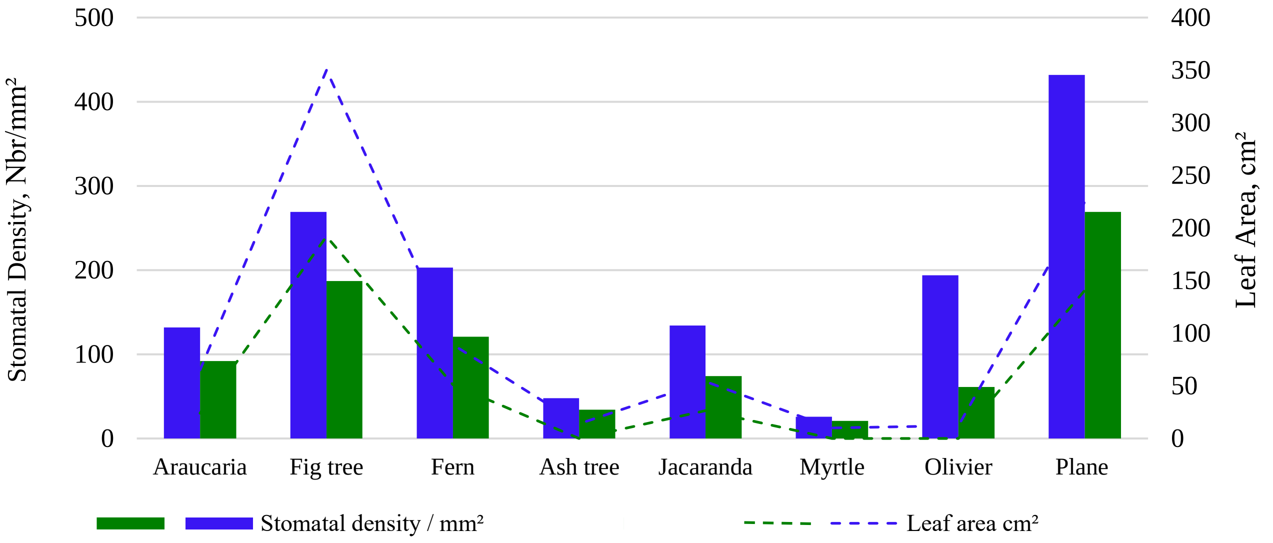

Figure 12. Stomatal density/leaf area

Source: authors' research, 2022.

Design concept. Following the data collection to systematize information about plant adaptations to high humidity, a biomimetic design methodology is proposed in the table below (Table 5), based on a mapping proposed by M. López et al. [35] to enable transferring biological strategies to architectural purposes.

Table 6

Design concept methodology

	Where	Adaptations' Challenges		Plane tree	Olive tree	Fig tree	Fern
Nature	Humid Mediterranean Climate	What?	Morphological		✓	✓	✓
			Physiological	✓			
			Behavioral			✓	
		Why?	Isolation	✓	✓	✓	✓
			Regulation	✓	✓		
			Impermeability	✓	✓	✓	✓
		How?		**Stomatic density**	**Coriatic cuticle Curved leaves shape**	**Velvety texture Hydrophobic substance**	**Multilayer structure**
				-Efficient gas exchange; -Facilitates photosynthesis	-Thermal insulation; -Reduces water loss; -Minimizes excessive water absorption; -Resistance	-Insulation that repels water prevents water droplets from accumulating and reduces the risk of increased fungal diseases caused by moisture	-Water drainage; -Efficient transpiration; -Prevent clogging
Constructions	Application idea	Design concept. Designing a building material		**Material Porosity** -The density of granules in the composition of construction materials	-External textures of the material and coatings	-Addition of adjuvants that reduce water infiltration into the composition of the material; -Biomaterial: Combine organic material with building material	-Design multi-layer building materials with layers dedicated to insulation, moisture resistance, and water vapor permeability

Source: authors' research, 2022.

1. *The high stomatal density* observed *in Plane trees'* leaves contributes significantly to plant insulation and thermoregulation. This feature is the outcome of physiological adaptations that enhance gas exchange and, hence, promote photosynthesis.

Application: development of porous materials with controllable porosity to regulate their permeability to air and water vapor. This mimicry improves the constructed environment's thermal regulation, impermeability, and insulation efficiency. This might be achieved with smart materials that respond to changes in humidity or with adjustable microporous architectures.

2. *The coriac texture* is one of the plants' morphological adaptations. For Olive leaves, this texture acts as a thermal insulator, helping to minimize water loss and prevent excessive water absorption in humid environments. It also resists infections and fungal diseases that thrive in high-humidity conditions.

Application: in architectural design, it refers to the exterior texture of building materials and cladding textures, inspired by the micro-texture of its cuticle to produce paints and self-cleaning surfaces that lessen the adhesion of pollutants and make their removal by rain easier. The curved edges of robust olive leaves can also serve as an inspiration for building outside buildings that are more resistant to strong winds and inclement weather.

3. *By secreting hydrophobic materials* on its leaf surfaces, the fig tree exhibits behavioral adaptability. As insulators, these substances keep water from standing and encourage the growth of mold. Physiologically speaking, the hairy leaves improve leaf ventilation, lessen moisture absorption, stop water loss, and shield the stomata from too high a humidity.

Application: hydrophobic additives can be included in the composition of building materials or coatings can be developed using hydrophobic polymers, waxes, or resins that repel water and prevent its infiltration into construction materials. In addition, the development of biomaterials based on natural fibers might enhance impermeability while maintaining their resilience to elevated humidity levels.

4. *Fern leaves,* with their protective outer cuticles and resistant inner layers, represent multi-layered structures that promote water drainage while ensuring efficient transpiration and preventing clogging.

Application: develop multi-layered building materials with layers of complementary properties: a hydrophobic outer layer dedicated to water permeability and an insulating inner layer for improved moisture resistance. Just as ferns absorb rainwater, a green roof can absorb rainwater, reducing runoff and helping to regulate building temperature.

Conclusions. Given the significant impact of climate change on ecosystems, it is becoming increasingly crucial to implement adaptive methods as a management strategy. This study examines the ways by which plants adapt to humid surroundings and proposes a method for applying these biological techniques to architectural design concepts. The aim is to create building materials and construction practices that can more effectively withstand and adapt to the challenges presented by humid climates.

This paper emphasizes the significance of comprehending plant adaptations to atmospheric conditions and incorporating this knowledge into numerous industries, such as architecture. It illustrates the substantial promise of biomimicry as a means of advancing sustainable design practices well-suited to humidity, particularly considering climate change.

Through microscopic analysis of leaf structures, it has been demonstrated that stomata density and distribution, as well as the presence of protective cuticles and hydrophobic structures, play a crucial role in plant adaptation to humid environments. Specifically, observations have revealed a high density of stomata on the underside of leaves, which helps to minimize transpiration, absorb ambient moisture, and preserve a stable water balance within the plant. Stomata also act as a protective mechanism by reducing direct exposure to moisture and excessive evaporation while still allowing for gas exchange and photosynthesis.

On the other hand, the upper surfaces of leaves are fortified with robust, leathery cuticles, hairs, and hydrophobic compounds, which serve to repel water, reflect light, and enhance airflow. These hydrophobic structures are particularly important as they prevent excessive water accumulation on the leaf's surface, which can lead to the formation of mold and other harmful pathogens. Overall, these microscopic observations shed light on the mechanisms that allow plants to thrive in humid environments and offer valuable insights for the development of technologies that can make such adaptations in architecture and other fields.

The distinguishing traits of plant adaptations to humid environments, including effective regulation of transpiration, absorption of ambient moisture, and maintenance of an optimal water balance, help to minimize the risk of fungal diseases. By analyzing the mechanisms by which plants in Jijel have adapted to high humidity, key principles have been identified that offer exciting potential for the development of innovative architectural solutions. These principles also provide a strong foundation for the creation of plant inspired building materials that are well suited to the demands of humid climates.

Plants’ adaptation mechanisms led to a focus on the porosity, external textures, hydrophobic additives, and multilayer structure of building materials to produce novel material compositions inspired by principles observed in plant species. This research lays the foundation for a bio-inspired architecture that is both durable and sustainable and can adjust to the unique climatic difficulties presented by humid environments.

Limitations and future research directions. The research is subject to several limitations that must be addressed in future studies. One significant challenge is the translation of laboratory successes to industrial-scale production, which may not always be feasible. The integration of new biomimetic components into existing building materials poses potential compatibility issues that require extensive testing and validation. Furthermore, the performance of biomimetic materials can vary significantly across different environmental conditions, limiting their universal applicability. Lastly, the advanced manufacturing techniques necessary for producing these materials are often prohibitively expensive, which could hinder their widespread adoption.

The findings underscore the transformative potential of integrating plant-inspired adaptations into material science, paving the way for more sustainable and resilient construction practices. Future research must prioritize the optimization of design and fabrication processes to enhance efficiency and reduce costs. Conducting long-term studies is essential to thoroughly evaluate the durability and performance of biomimetic materials under diverse environmental conditions. Interdisciplinary collaboration among botanists, materials scientists, and engineers is crucial to drive innovation in this field. The development and testing of prototypes in real-world conditions are critical to ensure their practical application. Finally, exploring genetic engineering to replicate plant adaptations in other organisms could pave the way for new material innovations.

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