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VASCULAR PLANTS COLONIZATION OF THE HISTORICAL CITY OF AZEMMOUR, MOROCCO

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ABSTRACT

From its Portuguese period, the historical city of Azemmour, on the Oum Errabia River banks, still boasts several monuments, including an imposing fortified wall. Among the factors of degradation that threaten this wall, we are particularly interested in the plant's action growing over this monument. The objective was to start by establishing a list of plant species colonizing the wall, then to deduce the potential effects that vegetation can have on the substrate. We carried out a systematic sampling in Azemmour. After sampling and identifying the plants, we established a list of 58 species, belonging to 26 families and 49genera. TheAsteraceae family is the most represented with 11 species, followed by Solanaceae with 6 species, Poaceae with 5 species and Amaranthaceae with 4 species. Depending on their life form category, these plant's roots are more or less intense, which leads to the dismantling of the masonry, and ultimately threatens ruin. The many medicinal plants found in the area are also a source of pressure on the site as they are anarchically uprooted by users. Devegetation measures must be undertaken urgently by conservators to control the spread of these plants in order to preserve the historic heritage.

Keywords: Vascular Flora, Biodeterioration, Historical monuments, Archeology, Azemmour

INTRODUCTION

The western part of the city of Azemmour is located on a narrow strip of sandy–muddy sediment, which is part of the Azemmour–Oued Massa sedimentological sector, oriented roughly north-south (Bayed, 1987). The ramparts of the Portuguese city of Azemmour have experienced four episodes of subsidence and collapse on several sides, more or less dangerous or even deadly. The Portuguese wall of the city of Azemmour suffers from multiple degradations resulting from the synergy of several natural and anthropogenic alteration factors, mainly biodeterioration. Indeed, for decades, vascular plants have covered several sections of the wall, actively contributing to its dismantling. Therefore, our study's objectives are to establish and analyze the inventory of plant species that colonize the wall, to determine their impacts, to propose elements of decision–making for monument conservators.

MATERIAL AND METHODS

Study area: The Medina of Azemmour (also called Azimur or Azzegour), a small city in the west of El Jadida province (Fig.1–A), is located at latitude 33°17'25''N and longitude 8°20'28"W, in the Doukkala plain, a fertile region rich mainly in cereals.

The city, built on a cliff above the left bank of Morocco's second-largest river (Fig.1–B), the Oum Errabia, about 3 km from the estuary on the Atlantic coast (Karra and Teixeira, 2008), benefits from a fascinating strategic location.

The Oum Errabia River, the longest river of the Kingdom with 600 km in length (El Gharbaoui, 1987), is a demarcation line between the north and south of the country. Its port was used for trade of products from the whole valley (cereals, olive, flax, shad...) and these economic resources have always been coveted, so much that the site has been occupied for over 2000 years (Carabelli, 2012). A stronghold of the dissident Berghouata Berber Kingdom in the 9th century, Azemmour was then successively marked by the passage of the Idrisside, Almohad, Merinid, and Wattasid dynasties before falling, in 1513, under the influence of the Portuguese. After about three decades of Portuguese presence, in 1541, Azemmour was taken over by the Saâdians, who had successfully achieved the political reunification of the whole country. Even today, the city of Azemmour testifies, through its monuments, to these different and successive passages (Chebri, 1999).

This study focuses exclusively on the city walls. Built under the reign of the Almoravids (Chahid, 2007) and reconsolidated by the Merinids in the 14th century, these ramparts were fortified for military purposes during the Portuguese occupation of the city of Azemmour. Since 1927, the Azemmour Medina's ramparts have benefited from legal protection as they were classified as historical monuments (B.O.N°790 1927).

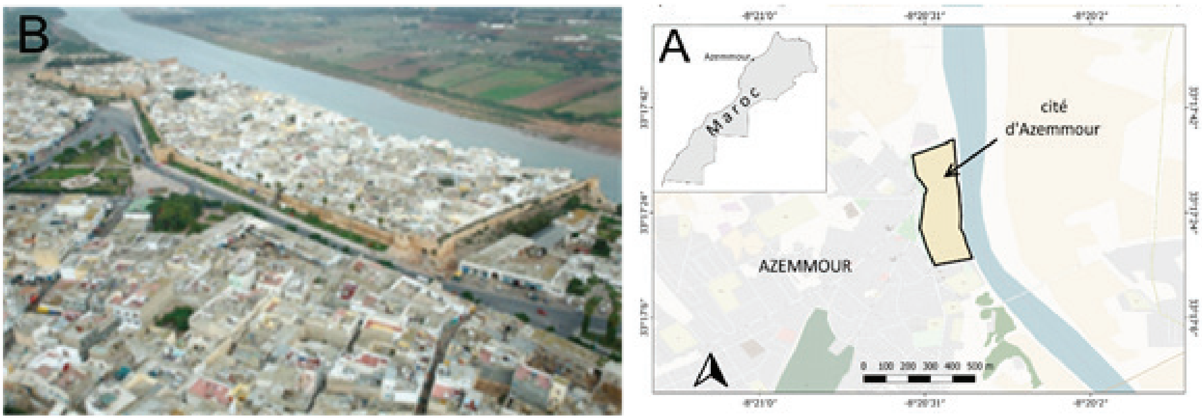

Fig.1. (A) Location of the study area, (B) Current aerial photo of the Azemmour Medina

The city belongs to a semi-arid bioclimatic zone with oceanic and fluvial influences. The average rainfall, calculated over 27 years from 1982 to 2009, is 367 mm (Rafik *et al.,* 2015); the average temperature varies from 12°C in January to nearly 23°C in July and August.

Methodology: The plants that colonize the city walls are carefully collected by random mechanical uprooting between March 2016 and January 2017. The small plants are entirely collected (root, stem, leaf, flower, and fruit). Shrubs and deep-rooted plants whose removal may damage the wall are not removed; the sample consists only of branches that will preferably bear flowers and, if possible, fruits. Species identification was carried out in the laboratory using reference documents such as (Fennane *et al.,* 1999, 2007, 2014) and recognized websites such as TelaBotanica (2018).

RESULTS AND DISCUSSION

Species richness in the Portuguese city of Azemmour: The examination of the plants collected from the ramparts of the Portuguese town of Azemmour led to identifying 58 plant species. *Lyciumeuropaeum* is the most widespread species. It can be observed at the top of the ramparts, on their bases in large stands, and even on their surface when the substrate's bioreceptivity (structure and chemical composition) allows the seed to stick and germinate (Guillitte, 1995). The list of species by family is as follows:

Amaranthaceae: *Amaranthus deflexus, Beta maritima, Chenopodium album, Chenopodium murale.* **Apiaceae**: *Ferula communis, Scandix pecten-veneris.* **Araceae**: *Arisarum vulgare*. **Arecaceae**: *Trachycarpus fortunei.* **Asparagaceae**: *Asparagus acutifolius*. **Asteraceae***: Anacyclus coronatus, Centaurea calcitrapa, Erigeron bonariensis, Leontondon saxatilis, Pallenis spinosa, Phagnalon saxatile, Scolymushis panicus, Senecio vulgaris, Sonchus oleraceus, Symphyotrichum squamatum, Xanthium spinosum*. **Boraginaceae**: *Echium humile*. **Brassicaceae**: *Diplotaxis catholica, Diplotaxis tenuifolia, Lepidium coronopus*. **Caryophyllaceae**: *Spergularia fimbriata*. **Convolvulaceae**: *Convolvulus althaeoides, Convolvulus arvensis,* **Crassulaceae**: *Umbilicus rupestris, Sedum sediforme*. **Euphorbiaceae**: *Ricinus communis, Mercurialis ambigua*. **Frankeniaceae**: *Frankenia laevis*. **Fabaceae**: *Lotus arenarius*. **Geraniaceae**: *Erodium ciconium*. **Malvaceae**: *Malva parviflora*. **Moraceae**: *Ficus carica*. **Oleaceae**: *Olea europaea.* **Oxalidaceae**: *Oxalis pes–caprae*. **Plantaginaceae**: *Kickxiacom mutata, Plantago coronopus*. **Poaceae**: *Ammophila arenaria, Catapodium rigidum, Cynodon dactylon, Hordeumm urinum, Piptatherum miliaceum*. **Polygonaceae**: *Emex spinosa, Polygonum aviculaire*. **Rubiaceae**: *Asperula arvensis*. **Scrophulariaceae**: *Misopates orontium*, *Verbascum sinuatum*. **Solanaceae**: *Hyoscyamus albus*, *Lycium europeum*, *Nicotiana glauca*, *Solanum Sodomaeum*, *Solanum nigrum*, *Lycianthes rantonnetii*. **Urticaceae**: *Urtica urens, Parietaria judaica*.

In the Portuguese city of Azemmour, we have recorded 58 species belonging to 49 genera and 26 families. The richest family is the Asteraceae with 11 taxa, followed by Solanaceae (6 species), Poaceae (5 species), Amaranthaceae (4 species), and Brassicaceae (3 species); the remaining families contain one or two species each (Fig.2 A). Solanaceaeare mainly represented by nitrophilous species, including *Hyoscyamus albus*, *Nicotiana glauca*, *Solanum sodamaeum,* and *Solanum nigrum,* which colonize areas rich in organic matter such as household waste and rubble. *Lycium europaeum* is a Solanaceae species/taxon remarkable for its presence in the region in general and on the city walls. The state of degradation of the city particularly favors the nitrophilous species of the Solanaceae family, whose coverage on the external surfaces of the walls is much greater than on their internal surfaces that are generally well maintained than the external sides.

The inventoried species belong to 5 life-form categories which are the therophytes (46.5%), hemicryptophytes (24.1%), phanerophytes (13.8%), geophytes (8.6%), and chamephytes (6.9%),(Fig.2–B). The therophytes, represented by 27 species, are followed by hemicryptophytes, represented by 14 species (Fig.2–B). These plants are characterized by a great potential for dissemination and germination; their light seeds take

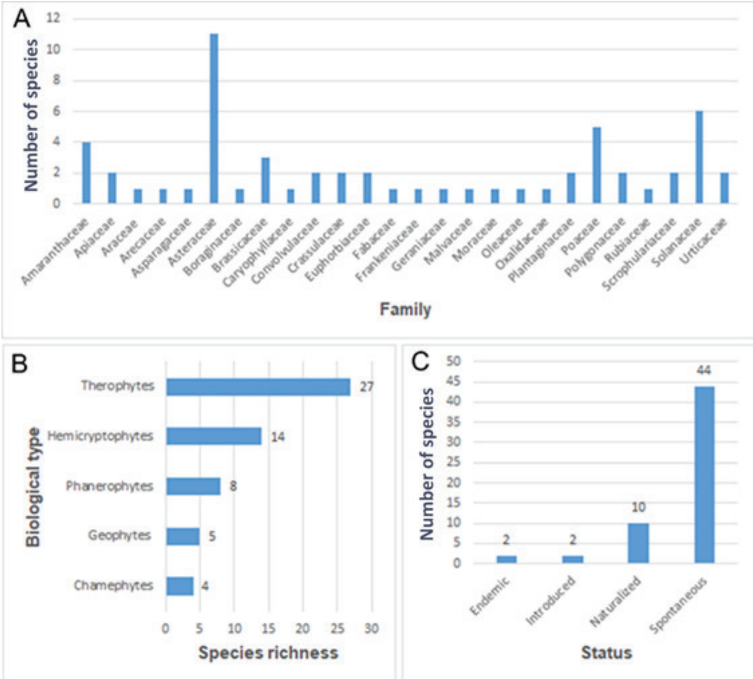

Fig.2 Species richness by family (A), by life form category (B), and by status (C)

advantage of the moisture accumulated on the walls and at their base to germinate and develop. This colonization provides the soil with organic matter that allows the installation of more demanding vegetation such as phanerophytes. Of these, *Lyciumeuropaeum* is the most abundant species. Geophytes have a low species richness with only 5 taxa, but their coverage is essential in the city, especially rhizome geophytes such as *Cynodondactylon,* which spreads through small cracks crevices in the substrate.

Depending on the life form category, plants can have strong rooting. Phanerophyte's roots, generally pivoting and strong would cause the most damage to the wall, as it sinks deeply into the substrate and causes mainly mechanical damage. The other species, if they have weaker roots, are no less harmful: bulbs (*Oxalis pes–caprae*), rhizomes (*Cynodon dactylon*), and tubers (*Arisarum vulgare*) of geophytes, for example, can exert intense pressures on the substrate, especially when they present significant overlaps as it is the case of the three above–mentioned species. These pressures can eventually contribute to cracking materials or even dismantling masonry stone or floor paving, thus opening the way to other alteration agents, mainly water.

Spontaneous species are the most numerous, with a population of 44 taxa (75.8%)(Fig.2–C). Of these species, nitrophile plants have the highest recovery rates. There are 10 naturalized plants (about 17.2%): *Umbilicus rupestris*, *Lycium europaeum*, *Nicotiana glauca*, *Ricinus communis*, *Solanum sodamaeum*, *Symphyotrichum squamatum*, *Oxalis pes–caprae*, *Anacyclus coronatus*, *Erigeron bonariensis* and *Xanthium spinosum***.** The natural spread of seeds explains the dominance of spontaneous species. There are also two introduced species observed on the ramparts: *Trachycarpus fortunei* and *Lycianthes rantonnetii***.** They were initially planted for ornamental purposes, but wind and animals spread their seeds and expanded their range in the study area, especially concerning *Lycianthes rantonnetii.* Two recorded species are endemic, the first *Pallenis spinosa* (L.) Cass. subsp. *aurea***,** endemic to Morocco and the Iberian Peninsula and the second *Lotus arenarius* Brot., endemic to Morocco, the Iberian Peninsula, and the Canary Islands.

The medicinal plants identified in the area (Table 1) and collected for phytotherapeutic purposes by the local population favor the cracking and deterioration of the antic walls. This is another pressure that is noted in this historic site. It would be judicious to sensitize the population and even to supervise it for the respect of the heritage. The collection of medicinal plants should be done by appropriate means such as pruning shears instead of brutal extraction. Better than that, this kind of collection should be completely forbidden on the site.

Substrate and environmental conditions: Edaphic and microclimatic factors significantly influence the range of plant species. The north and west exposed areas are richer in plants compared to the south and east facing surfaces due to the humidity gradient. The anthropogenic factor also comes into play: household waste disposal areas are colonized by nitrophilious vegetation. Most of the species harvested are light demanding and prefer warm to moderately hot, relatively humid environments. The observation of the Medina wall of Azemmour reveals a significant presence of vascular plants that have developed over very large areas. The wall has undergone several phases of construction, reinforcement and restoration; nevertheless, the proliferation of vegetation on these ramparts, on several sections and at different levels, contributes greatly to reduce the disparities, giving the whole an apparent homogeneity.

Vegetation settles on different supports and substrates. Thus, the plants grow on the earthy substrate of the Islamic parts of the wall that have used the local technique of rammed earth.This technique for building walls use a clay and sandy natural soil. A rammed earth wall is built by placing damp soil in a temporary form. The material is manually compressed into place with forms that create very flat vertical surfaces.

Plants are also abundant in large sections of the wall that were consolidated and fortified during the Portuguese occupation. The constructive principle was based on the construction of masonry walls made of quaternary calcarenite rubble flush in the region, and terracotta bricks, all joined by lime mortar (Khouaja *et al.,* 2016).

The basis of the outer enclosure and its various towers, with protruding masonry reinforcements designed

Fig. 3. Vegetation colonizing the ashlar enclosure adjoining the "U" shaped Porto–bastion (B) as well as its walls inside (A) and the floor (C) losing all reading of the site

to optimize its protection, is also invaded by vegetation (fig. 3).

Vegetation also invades the natural bedrock of the earth side wall. In this case, the enclosure rests on a thick bank of consolidated quaternary coarse fluviomarine conglomerates that form a promontory several meters above the Oum ErrabiaRiver(Khouaja *et al.,* 2016).

Impact of plants: The impact of higher plants in the field of conservation of archaeological sites and historic monuments (Winkler, 1975; Caneva *et al.,* 1991; Caneva *et al.,* 2009; Mishra *et al.,* 1995; Ceschin *et al.,* 2016) is not controversial contrary to plants such as lichens, algae (Gehrmann 1988; Crispim *et al.,* 2005; Lombardozzi *et al.,* 2012; Warscheid and Braams, 2000) or ivy (Bartoli *et al.,* 2016).

The uncontrolled proliferation of vascular plants on historic monuments,with lack of maintenance, is a significant additional factor of disorder.This issue has been the subject of numerous publications worldwide. Indeed, several studies have focused on the identification and inventory of plants that invade historical monuments (Guglielmo *et al.,* 2006; Ceschin *et al.,* 2006; Distefano *et al.,* 2009; Motti and Stinca, 2011).In Morocco, some historic sites have also been the subject of a census of the species that settled there at the expense of their durability (Zaidi *et al.,* 2016, Elharech *et al.,* 2017, Dahmani *et al.,* 2018). From the floristic point of view,the city of Azemmour is quitesimilar to the city of Mazagan (Dahmani *et al.,* 2018) because of their location on the Central Atlantic Moroccan coast. In fact, the two cities have 96 species, of which 38 are common with a similarity index of 39.6%. However, Azemmour differs from Mazagan with its important plant colonization that is considerable.

All these plants draw water and mineral salts necessary to their growth by their roots. When these elements are lacking, the roots lengthen deeplyby hydrotropism to reach other reserves; this phenomenon then generates a weakening of the structure and can even cause irreversible damage to walls (Dahmani *et al.,* 2018).

In fact, the structural stability of wallsdepends intimately on the integrity of joints, the tightening of blocks, and the absence of cracks. However, the growing roots exert a strong pressure that can reach 15 bars (Winkler, 1975; Caneva and Galotta; 1994), capable of threatening the integrity of the structuresby precisely showing these anomalies.

In addition to this physical aspect of biodeterioration, chemical processes also occur. They develop because of the acidity of the root tips and the acidic and chelating abilities of the various root exudates that react chemically with the surface of substrates(Jain *et al.,* 1993; Pinna and Salvadori, 2005).

Moreover, plant growth is likely to increase the risk of fire in dry conditions and may also promote other degradation factors by causing changes in the microclimate that may lead to the growth of other forms of biodeteriorogens or by harboring pests and microorganisms (Fisher, 1972). Similarly, the presence of plants on the wall's surface or foundationcan maintain high level of humidity (Ashurst and Ashurst, 1988).

Furthermore, the density of plants makes it very difficult or even locally impossible to read architectural elements in some places. The siding is covered by plants and shrubs whose roots fit into the masonry joints while mosses and lichens cover the surface of the substrates (Fig. 3).

The spontaneous proliferation of plants had disastrous consequences for the Azemmour's wall. Indeed, although the wall has already been restored in 1994, collapses have followed one another since 2011 and have affected several sectors.

The first collapse occurred in 2011, at the south–eastern wall on the side of the bastion called "Bab Jiaf" (Ramdani, 2016). In 2012, a second collapse occurred over a length of 25 meters long and 10 meters wide (Lokhnati, 2012).The collapses have resumed in 2014, affecting two parts of the wall facing "Bab Al Makhzen" and "Bab Sidi Al Makhfi", (Ramdani, 2016). The last collapse episode occurred in 2016. Since then, an emergency program has been planned for the safeguarding of the wall and work is still ongoing today.

CONCLUSION

While vegetation often adds cachet to a historic monument, plants are often source of many inconveniences such as substrate humidification, cracking masonry, or even dismantling of buildings.

Biodeterioration is indeed an almost inevitable result of the interaction of masonry with the environment, especially when materials are not sufficiently isolated from all factors that promote organic growth.The determination of the species involved is essential for understanding the adverse effects of plants on structural elements.

Most of the species recorded develop spontaneously on walls, at the base of walls, at the edges and on paths. It should also be noted that many plants are used as medicinal plants and therefore are pulled out anarchically by the population which increases the pressure on the antic walls.

Therophytes and hemicryptophytes are the richest

Table 1: List of medicinal plants collected in the Portuguese city of Azemmour, Morocco.

Species	**Parts used**	**Ethnobotanical uses Phyto-therapeutic action /Disease**	**References that indicate their uses**
Ferula communis	Gum resin	Pyelonephritis, cystitis and urethritis	Benkhnigue *et al.,* (2016a) ; (2016b)
	Leaf	Diabetes	Chaachouay *et al.,* (2019a)
	Root	Rheumatic pains by massaging the feet	Hachi *et al.,* (2016b)
	Rhizome	Pimples, disease or skin	Ben akka *et al.,* (2015)
	Leaf	Hyperthyroidism	Chaachouay *et al.,* (2019a)
Asparagus acutifolius	Aerial part	Use in cosmetics	Bouhlal *et al.,* (2013)
Pallenis spinosa	Aerial part	diabetes	Benkhnigue *et al.,* (2014)
Scolymus hispanicus	Leaves/ Stem	diabetes	Hachi *et al.,* (2016a) et Benkhnigue *et al.,* (2014)
Ricinus communis	Seeds	Use against cooling	Hachi *et al.,* (2016b)
	Seeds	Purgative, healing	Ben akka *et al.,* (2015)
	Leaf	Headache	Benkhnigue *et al.,* (2010)
	Oil	Use in cosmetics	Bouhlal *et al.,* (2013)
Ficus carica	Fruit	Respiratory diseases	Ben Akka *et al.,* (2017)
	Fruit	Hemorrhoids, menstruation pain, antispasmodic, diuretic	Ben akka *et al.,* (2015)
	Leaf	Diabetes and Hypercholesterolemia	Chaachouay *et al.,* (2019a)
	Fruit	Large intestine pain, antimicrobial, antioxydant.	El Azzouzi., (2018)
	Leaf	Diabetes	Chaachouay *et al.,* (2019a)
	fruit peel	Diabetes	Benkhnigue *et al.,* (2014)
	Fruit + Latex	Use in cosmetics	Bouhlal *et al.,* (2013)
Olea europaea	Oil	Respiratory diseases (Influenza, cough)	Ben Akka *et al.,* (2017)
	Oil	Pain in the joints	Hachi *et al.,* (2016b)
	Oil and leaf	Diuretic, hypotensive, decrease-cholesterol, laxative	Ben akka *et al.,* (2015)
	Leaf	Anti-diabetes, antioxidant	El Azzouzi., (2018)
	leaf and fruit	cystitis and pyelonephritis	Benkhnigue *et al.,* (2016a)
	Oil and leaf	Diabetes	Benkhnigue *et al.,* (2014)
Cynodon dactylon	Rhizome	Tuberculosis	Chaachouay *et al.,* (2019b)
		Inflammation of the bladder, diabetes	Ben akka *et al.,* (2015)
		Renal lithiasis	Benkhnigue *et al.,* (2016b)
		Cystitis (bladder cooling)	Benkhnigue *et al.,* (2016a)
Polygonum aviculaire	Leaf	Joint pain	Ben akka *et al.,* (2015)
Hyoscyamus albus	Leaf	Cystitis	Benkhnigue *et al.,* (2016a)
Solanum sodomaeum	Seeds	Diarrhea, Antioxidant	El Azzouzi., (2018)
Solanum nigrum	Fruit	Against constipation, antispasmodic, analgesic, sedative	Ben akka *et al.,* (2015)
	Leaf	Use to treat wounds and injuries of people with diabetes	Benkhnigue *et al.,* (2014)

in species in the Portuguese city of Azemmour, while phanerophytes, geophytes and chamephytes are less due to the high spread and germination capacity of the therophytes's and hemicryptophytes's seeds compared to other life form categories.It should be noted, however, that *Lycium europaeum* is the phanerophyte with the largest recovery.

In Azemmour, the state of the wall is relatively worrying.It is therefore essential and urgent to initiate a good safeguarding program to restore the endangered masonry and secure the site for visitors.

The operations to be carried out, the devegetation, cutting and dismantling of trees, the resumption of cracks, the repair of joints with lime mortar, the consolidation or even the reconstruction of stone masonry must be carried out in accordance with the laws and standards for the protection of historic monuments and preserving the environment.

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