International Biodeterioration & Biodegradation 133 (2018) 26–33

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Vascular plant colonisation of four castles in southern Italy: Effects of substrate bioreceptivity, local environment factors and current management

Riccardo Motti*, Giuliano Bonanomi

Department of Agricultural Sciences, University of Naples Federico II, Via Università 100, 80055, Portici (NA), Italy

ARTICLE INFO

Keywords:
Biodeterioration
Higher plants
Bioreceptivity
Hazard index
Monument conservation

ABSTRACT

Biodeterioration, the alteration caused by living organisms, on historical buildings and stone monuments is a widespread problem affecting two-thirds of the world's cultural heritage. Deterioration and weathering of stone monuments are caused by abiotic, anthropogenic and microbial factors, with few studies focusing on the role of higher plants. In this study, we investigate how rock type, exposure and inclination of the wall, as well as current management, affect the biodeteriogenic vegetation at four stone monuments. For this purpose, we selected four castles situated in the province of Naples in southern Italy. For each castle, we analysed linear transects 1 m long (N = 74), representing the different associations of the main biodeteriogenic vascular plant species. The total number of plant species recorded was 28, belonging to 17 families. Floristic composition and hazard index (HI) varied greatly among the four study sites. Exposure, substrate type and surface inclination significantly affect floristic composition, with plant cover and HI highest on south-facing walls. As regards the rock substrate, HI was significantly higher on plaster, compared to piperno and tuffs. Finally, substrate inclination did not affect plant occurrences although the HI was significantly higher on horizontal surfaces than vertical ones. Our study revealed that the walls of four castles harboured specific flora, whose composition depends on local environmental factors, current management as well as the surrounding vegetation. The present findings concerning the colonisation capabilities of the main biodeteriogenic species provide useful insight to clarify the relationship between plant cover and hazard risk in the context of wall deterioration.

1. Introduction

The problem of deterioration of cultural heritage is particularly significant in countries, such as Italy, that are rich in historical buildings and monuments. According to UNESCO (United Nations Educational, Scientific and Cultural Organization) data, Italy possesses two-thirds of the world's cultural heritage. Most of the available knowledge about deterioration concerns alteration and weathering of stone caused by abiotic, anthropogenic, and microbial factors (Nuhoglu et al., 2006). Indeed, a number of works have focused on the role of microbiota, including bacteria, fungi, as well as lichens and mosses, on the biodeterioration of stone monuments (Warscheid and Braams, 2000; Scheerer et al., 2009). In recent decades, however, several studies have recognized the importance of higher plants in causing damage to stone monuments (Lisci and Pacini, 1993; Signorini, 1996; Kumbaric et al., 2012).

In terrestrial ecosystems, plants can induce changes in soil chemical and physical quality through several mechanisms: direct extraction of organic compounds from roots (Gregory, 2006), or during decomposition of plant litter (Bonanomi et al., 2011a), and indirectly by the modification of soil microbiota (Berendsen et al., 2012). In the long term, the plant is able to modify its rooting substrate by continuously adding organic matter through litterfall and root turnover which, thus, contributes to soil formation (Jenny, 1994). The capabilities that make plants able to colonise bare substrates and, during succession, to create fertile soil are the same as those that make these sessile organisms able to cause damage to stone monuments. Roots penetrate building material, and during growth can dislodge even very large stones (Kumar and Kumar, 1999). Dust trapping and the accumulation of organic matter and nutrients, due to root turnover, create pockets of fertile soil among stone (Gómez-Alarcón et al., 1995).

In natural plant communities, plant establishment and growth is closely related to soil quality, local microclimatic conditions, and the net interaction with other plants (Callaway and Walker, 1997). In this regard, walls are an anthropic, highly selective and, in some way, an extreme habitat (Ellenberg, 1996; Laníková and Lososová, 2009). In stone monuments, the chemical features of the rock, the microclimatic conditions in relation to exposure and inclination, as well the previous

* Corresponding author. Tel.: +390812532014.
E-mail address: motti@unina.it (R. Motti).

https://doi.org/10.1016/j.ibiod.2018.06.004
Received 4 February 2018; Received in revised form 5 June 2018; Accepted 5 June 2018

interaction with other biodeteriogenous factors control the ability of plant to colonise such ecosystems. The susceptibility of a substrate to biological colonisation has been defined as bioreceptivity (Guillite, 1995). Bioreceptivity depends on the physical and chemical properties of material to be colonised, as well as on previous use in terms of chemical and biological weathering (Warscheid and Braams, 2000). For instance, bioreceptivity is higher for porous rocks which, because of this property, adsorb and retain more water (Kumbaric et al., 2012).

Higher plant colonisation of stone monuments is limited by several factors, including the availability of safe sites for settlement, the hardness of the substratum, frequent disturbance, the large variability of microclimate in terms of temperatures and humidity, as well as the scarcity of water (Segal, 1969; Ceschin et al., 2016). Nonetheless, many vascular plant species are able to colonise and establish in rocky walls. The specific ecological conditions of stone walls act as a filter, allowing colonisation of a specific flora but excluding most of the species that reach this habitat with their seeds. Understanding the factors that control plants colonising stone monuments can help to shed light on the potential harmful effect of these plants on these structures. Thus, a better knowledge of the bioreceptivity concept is a useful step for proper management of stone monuments.

In this study, we investigate how rock type, local factors in terms of exposure and inclination of walls, and anthropogenic disturbance, in terms of site management, affect the distribution of vascular plants in stone monuments. To achieve this aim, we selected four castles situated in the Naples metropolitan area (Fig. 1). Naples and its province are characterised by the presence of a large number of historic buildings and monuments that can be dated from the 6th century to the middle of the 19th. One of the main problems in managing and conserving this great historical and artistic heritage is posed by the processes of biodeterioration, whose main role is played by the growth of higher plants (Motti and Stinca, 2011). In this context, the aim of the present work was to analyse the impact of biodeteriogenic vascular flora and assess the effect of stone construction materials, local environmental conditions, and ordinary management on biodeteriogenic plants.

2. Materials and methods

2.1. Study sites

Three of the four castles are situated in the Naples metropolitan area (Maschio Angioino, Castel dell'Ovo and Castel Sant'Elmo) and one in the Phlegraean Fields in the Municipality of Baia (Aragonese Castle of Baia) (Fig. 1).

2.1.1. Castel dell'Ovo

Castel dell'Ovo (hereafter referred to as Ovo) is the oldest standing fortification in Naples. Situated on the small island of Megaris, it is connected to the mainland by a short isthmus (Fig. 1). The first construction dates back to the first century BC as a villa of a Roman patrician. Fortified in the mid-5th century, it was demolished in the ninth century and re-built by the Normans in the twelfth century. The current appearance dates back to the Aragonese domination (fifteenth century). It is entirely built with yellow tuff blocks, and the side exposed to the west is in close contact with the sea. It is located at 0 m a.s.l. and the distance from the sea is 0 m (Table S1).

2.1.2. Maschio Angioino

Maschio Angioino (Maschio), also known as Castel Nuovo, is a medieval castle built in 1282 and located in the historical centre of Naples. Enlarged in the first half of the 14th century, the fortress was completely rebuilt in its present shape by Alfonso V of Aragon. The

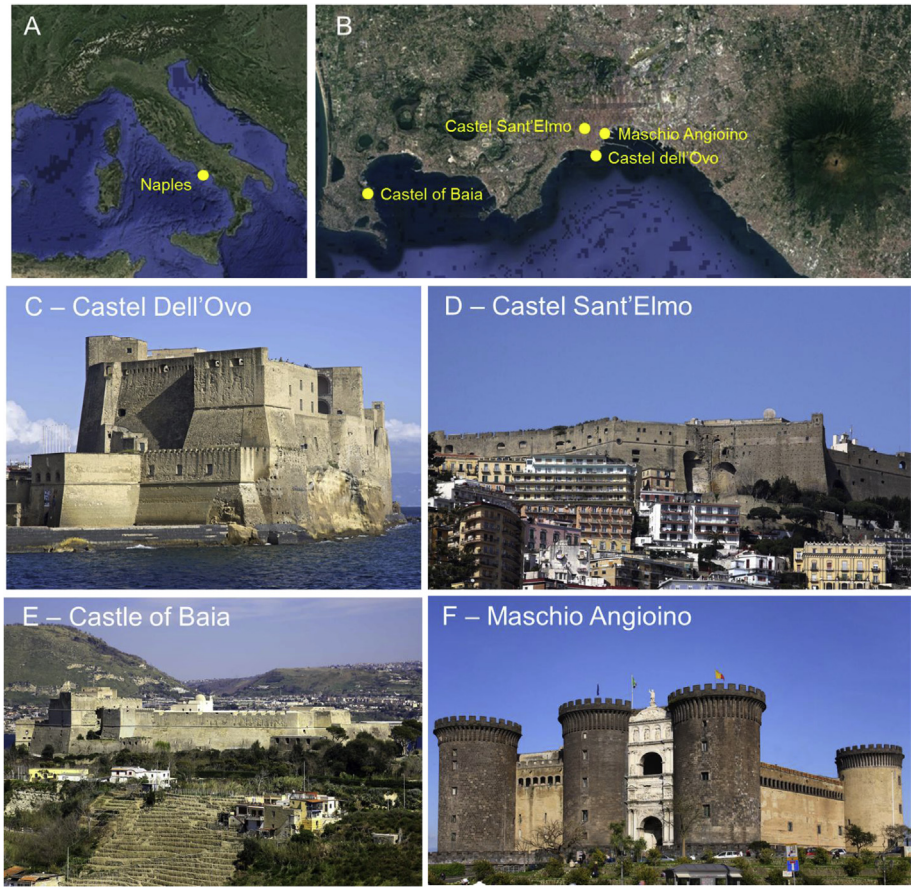

Fig. 1. Study site (A), location of the castles in the Naples metropolitan area (B), and images of the castles in question (C, D, E, and F).