







Biodeterioration of Monuments: A Research in Teos Antique City, Türkiye

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Abstract

The aim of our study was to reveal the fungal degradation in the historical monuments in the ancient city of Teos. In the antique city of Teos, which is estimated to exist since the protogeometric period, field studies have been carried out on monuments exposed to fungal deterioration. As a result of the field studies carried out in Teos, it was observed that especially cauliflower-like black microcolonial fungi, caused alteration in historical artifacts. These fungi have been found to cause brown to black coloration, crater-shaped pits, blistering and fracture, and belong to the genera *Capnobotryella*, *Cladosporium*, *Coniosporium*, *Lophiostoma*, *Massarina*, *Monodyctis*, *Mycocalicium*, *Phoma*, *Phaeococcomyces*, *Rhinocladiella* and *Sarcinomyces*. The deterioration of historical artifacts is a threat in the ancient city of Teos, as in the whole world. It is necessary to increase both biological diversity and biological control studies in this field.

Keywords:

Black microfungi, fungal deterioration, Teos

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Introduction

Historical artifacts, which are our cultural heritage, are exposed to many biological, physical, and chemical threats (Negi & Sarethy 2019; Cappitelli et al., 2020; Schumacher & Gorbushina 2020). Microorganisms can cause serious biodegradation on historical buildings, such as fungi, bacteria, algae, lichens, and cyanobacteria (Sert & Akdeniz 2017; Bruno et al., 2019; Sert 2019). Fungi in

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particular play an important role in the deterioration of cultural heritage. Due to their enzymatic activities and their ability to develop at low aw values, fungi can easily survive in materials used for historical art objects such as textiles, paper, parchment, leather, oil, casein, and glue, and cause deterioration (Sterflinger, 2010). Fungi also cause color changes, crusting, swelling, and crumbling in historical stone buildings (Sterflinger, 2005; 2010; Sert et al., 2017; Negi & Sarethy, 2019; Sert, 2019). Due to the strong melanization of the cell walls, fungi called black microfungi or Dematiaceae, cause serious deterioration on stone monuments. The main effects of these microorganisms on stone monuments are as follows; color changes and deposits on the surface of buildings that significantly disrupt the aesthetics; physical and mechanical effects, various organic-inorganic acids, gases and their combined reactions (biocorrosion) released into the environment (Sterflinger & Krumbein, 1997; Sterflinger et al., 1998; 1999). They cause crater-shaped pits, that from 2 μm to 2 cm in size. With the effect of these fungi, it becomes difficult to read relief writings on sarcophagi and other structures and to recognize pictures (Staley et al., 1982; Çorapçioğlu, 1983; Eckhardt, 1985; Sterflinger et al., 1998; Sterflinger, 2005; Sterflinger, 2010).

In this study, black microfungi causing deterioration on monuments in the ancient city of Teos, were detected. The antique port city of Teos, was established on the strait of a small peninsula (Isthmos). The acropolis of the city is located on Kocakırtepe. Teos Ancient City is the oldest and the most important historical ruin of the county (www.kultur.gov.tr (02.01.2022)). Teos, one of the 12 Ionian cities, was founded for the first time in 1080 BC by Akalı Commander Athamas. The first structure that appears when you come to Teos, which is in the middle of the ports to the south and north, is the Dionysos Temple built by the greatest architect of the Hellenistic period, Hermogenes, in the name of Dionysus, the patron god of Teos. To the south of the temple is a water reservoir, most of which is still standing today. Apart from these, the Ancient Harbor, the Archaic Temple (Hekatompedon), the Ancient Theater at the foot of the Archaic Period Acropolis and the Agora, Agora Temple, Bouleuterion, Cistern and Ancient Roads located in the southeast of the theater are some of the important public buildings (www.kultur.gov.tr (02/2022)). In this research, black microcolonial fungi that cause deterioration on all these historical stone structures in the ancient city of Teos were determined and the decay effects of these species were observed.

Materials and Methods

This study is carried out in the antique port city of Teos, located in the Sığacık District (Seferihisar) of Izmir Province, is approximately 60 km southwest of Izmir (Aegean Region, Türkiye) (Figure 1). In 2019, in all seasons, samples of different sizes were scraped from the stone surface with the help of a hammer, knife or scalpel. The samples were taken, placed in paper bags and kept until preparation and microbiological processes. Macro and microscopic photographs were taken. For the isolation of black microfungi, the stone fragments were washed with 70% alcohol and examined under a stereo microscope. Colonies were taken with a sterile channeled needle and transferred to malt extract agar (MeA) and dichloran rose bengal (DRBC) media. Microfungi grown on media

were isolated again from petri dishes and inoculated on malt extract agar, czapek agar (CzA) and potato dextrose agar (PDA) media.

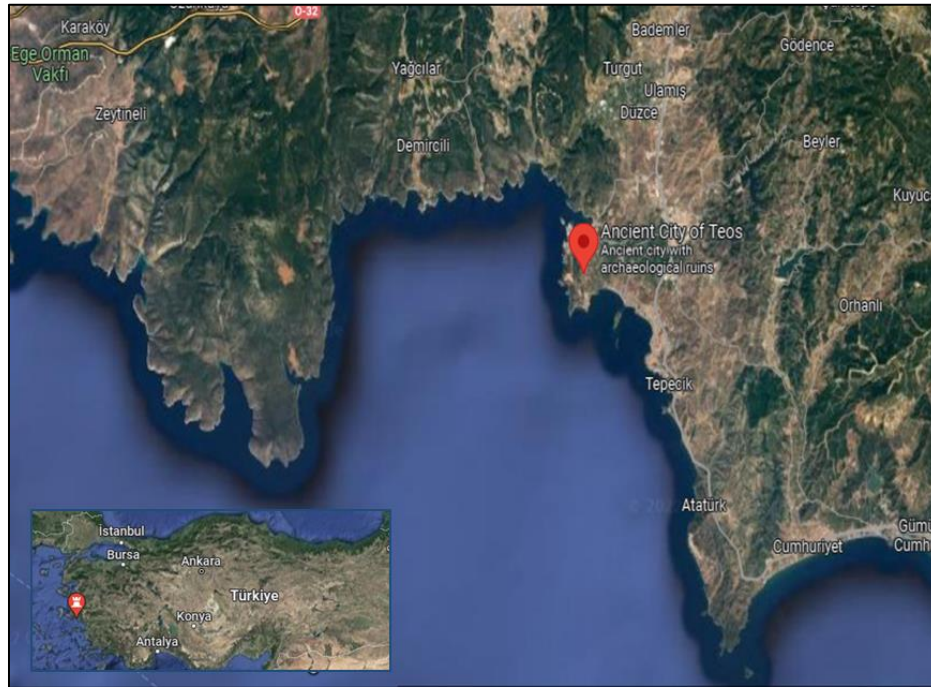


Figure 1. Satellite view of Teos Ancient City, Sığacık. (Seferihisar, İzmir)

For morphological characterization, samples were examined under stereo and binocular microscope, macro and microscopical characteristics and were determined. The determination of black microcolonial fungi using morphological characters is quite problematic. Therefore, species identification is performed by molecular genetic methods. Sample collection, isolation, morphological, and molecular characterization are carried out according to (Sert et al., 2007). The Internal Transcribed Spacers (ITS regions), which are nested in the nuclear rDNA repeat, have been selected to investigate the fungal diversity of fungi on monuments (Sert et al. 2007a; 2007b; 2007c; Onofri et al. 2014). The ITS regions possess a high variation between taxonomically distinct fungal species and even within the species.

Results and Discussion

The decay of historical artifacts is a threat in the ancient city of Teos, as in the whole world. Pollution, atmospheric factors and different effects are the main causes of the degradation of cultural heritage and microorganisms that often cause irreversible damage. The deterioration on historical artifacts poses a problem to the transfer of cultural heritage to future generations. In addition to mechanical applications, chemicals are also used for preventing damage to historical artifacts, removing fungal-lichen colonies, and for sedimentation problems. Chemicals used in the maintenance, repair, restoration, and conservation processes of cultural structures can damage the

natural ecosystem to prevent the development of microorganisms that damage the structure in the long term. It is necessary to develop biological control methods, considering the possibility of harm caused using chemicals. Meanwhile, studies on species identification should continue. (Sert et al., 2011; Sert et al., 2012; Sert & Akdeniz, 2017).

Various studies on black microcolonial fungi, in other words meristematic fungi (due to their meristematic morphology), have been conducted in many different countries of the world (Gravesen et al., 1994; Sterflinger & Krumbein, 1997; Sterflinger et al., 1998; Sert et al., 2007b; Sert et al., 2007c; Sert & Sterflinger, 2009; Sterflinger, 2010; Sert et al., 2011; Sert et al., 2012; Sert & Akdeniz, 2017; Sert, 2019; Bruno et al., 2019; Ghany et al., 2019; Liu et al., 2020; www.kultur.gov.tr (02/2022)). In Türkiye; in Side, Perge, Termessos, Trabenna, Ephesus, Phokaia, Olympos and Seleukeia was carried out studies on these fungi. There are differences in terms of climatic data and altitude between the areas where these studies were conducted. However, the results are almost parallel to each other. In areas close to the sea, degradation is much higher due to wind-borne salt and high humidity. Many fungal species, including black yeasts were recorded from monuments of antique city in Türkiye. The majority of these species are black microfungi with meristematic morphology, well adapted to high stress conditions. Rock-inhabiting fungi (RIF) are very active agents causing visible alteration patterns and exfoliation of stone monuments; ecological conditions in the Mediterranean rocks are optimal for RIF development (Onofri et al., 2014).

During the field studies carried out in Teos ancient city, it was observed that especially cauliflower-like black microcolonial fungi, caused alteration in historical artifacts (Figure 2). These fungi have been found to cause brown to black coloration, crater-shaped pits, blistering and fracture and belong to the genera *Capnobotryella*, *Cladosporium*, *Coniosporium*, *Lophiostoma*, *Massarina*, *Monodyctis*, *Mycocalicium*, *Phoma*, *Phaeococcomyces*, *Rhinocladiella*, and *Sarcinomyces*. The species are as follows; *Capnobotryella renispora*, *Capnobotryella* sp., *Cladosporium cladosporioides*, *C. elatum*, *C. sphaerospermum*, *Cladosporium* sp., *Coniosporium apollinis*, *Coniosporium* sp., *Lophiostoma arundinis*, *Massarina papulosa*, *M. rubi*, *Monodyctis.castaneae*, *Mycocalicium victoriae*, *Phaeococcomyces catenatus*, *P. chersonesos*, *Phaeococcomyces* sp., *Phoma herbarum*, *Rhinocladiella phaeophora*, *R. aquaspersa*, *Rhinocladiella* sp., *Sarcinomyces* sp., *S. petricola* (Figure 3).

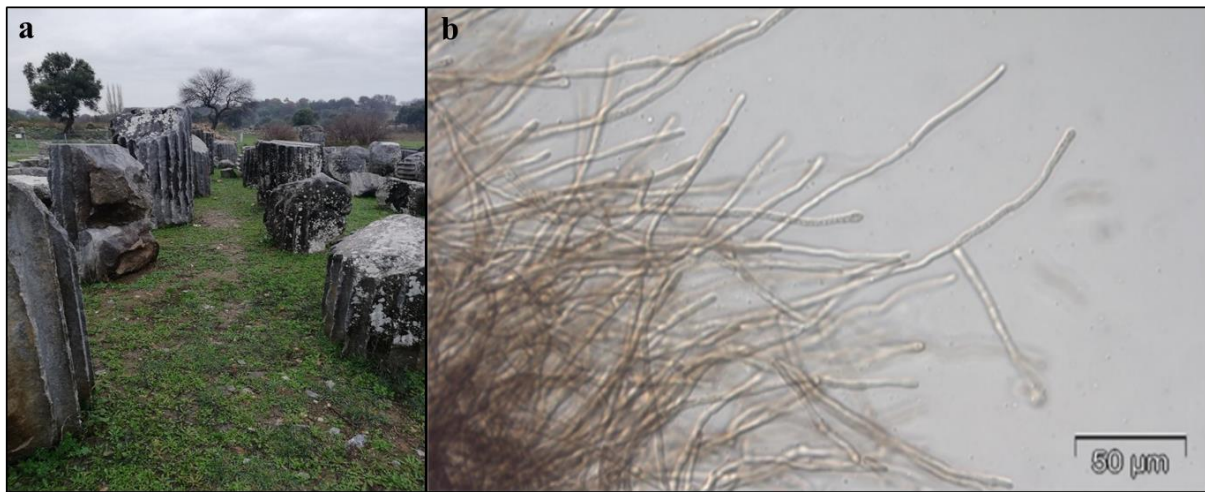


Figure 2. a) Microbial corrosion in the ruins of the ancient city of Teos, b) Hyphal extensions of *Sarcinomyces* sp.

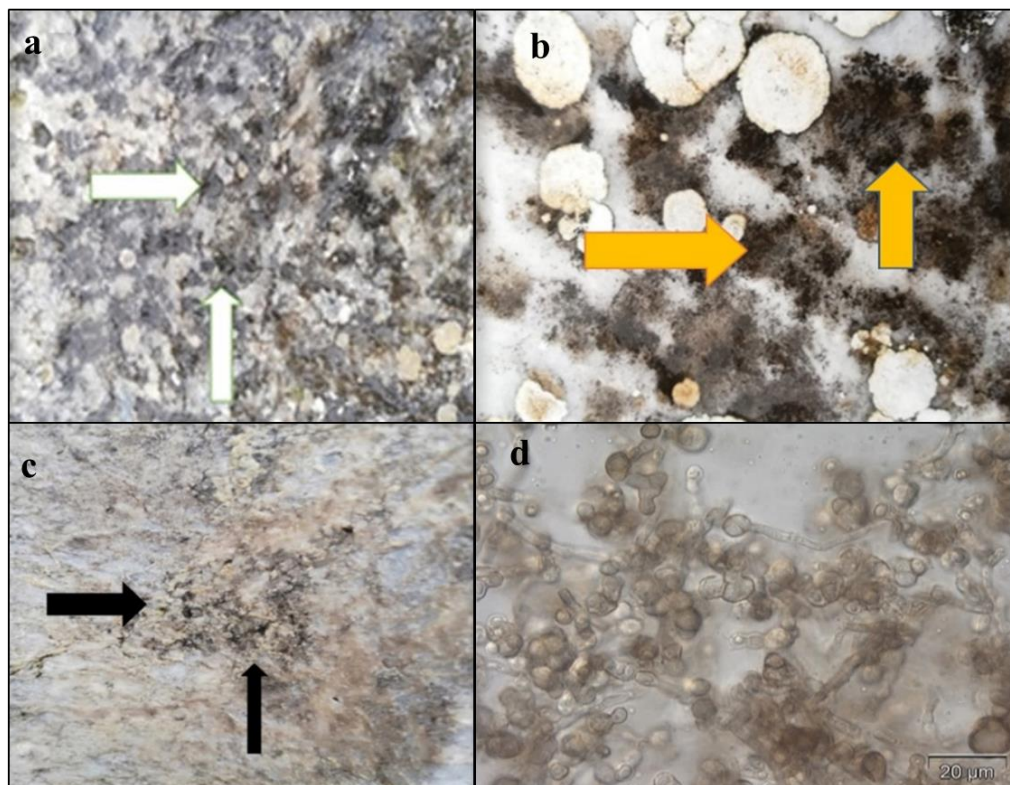


Figure 3. (a, b, c) Close view of the colonies formed by black microfungi on historical artifacts in the study area, d) Conidia of *Capnobotryella renispora*

In conclusion, since the ancient city of Teos is located in a region close to the sea, it is observed that black microfungi, which are very resistant to stress factors, especially called meristematic

fungi, are found in the historical artifacts in the ancient city. Although the excavations in the ancient city are carried out very meticulously, struggle studies should be planned in the coming years.

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Author Contributions

Field work and manuscript writing is done jointly with all authors.

Conflict of Interest

The authors declare that they have no conflict of interest.

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