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Vascular plant diversity of the Alanya Castle walls and their ecological effects

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Abstract

Since historical buildings are living mirrors of the past, it is very important to preserve and transfer them to future generations. In this study, plants growing on the walls of Alanya Castle were identified and the damages that these plants gave to the historical construction and the precautions to be taken to prevent these damages were emphasized. A total of 94 plant taxa, including five pteridophytes, one gymnosperm and 88 angiosperms, belonging to 35 families were identified on the walls of Alanya Castle. *Conyza canadensis, Inula heterolepis, Phagnalon graecum, Arabis verna, Mercurialis annua, Fumaria parviflora, Cymbalaria microcalyx, Galium canum* subsp. *antalyense, Parietaria judaica, Hyoscyamus aureus, Poa bulbosa* were the dominant plant species of Alanya Castle walls. Possible seed dispersion of these plants on the castle walls and the methods for controlling them are discussed in detail. We conclude that the most effective method of combating plants that grow naturally on historical buildings and give damage to these buildings is mechanical excavation.

Key words: Alanya, biodiversity, mechanical excavation, urban ecosystems, wall flora

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Alanya Kalesi duvarlarının vasküler bitki çeşitliliği ve ekolojik etkileri

Özet

Tarihi yapılar geçmişin yaşayan aynaları olduklarından, onları korumak ve gelecek nesillere aktarmak çok önemlidir. Bu çalışmada 2015-2017 tarihleri arasında Alanya Kalesi duvarları üzerinde yayılış gösteren bitkiler belirlenerek, bu bitkilerin tarihi yapılara verdikleri zararlar ve bu zararları önlemek için alınması gereken tedbirler üzerinde durulmuştur. Alanya Kalesi duvarlarında 35 familyaya ait 5 eğrelti, bir açık tohumlu ve 88 kapalı tohumlu olmak üzere toplam 94 bitki taksonu belirlenmiştir. *Conyza canadensis, Inula heterolepis, Phagnalon graecum, Arabis verna, Mercurialis annua, Fumaria parviflora, Cymbalaria microcalyx, Galium canum* subsp. *antalyense, Parietaria judaica, Hyoscyamus aureus, Poa bulbosa* Alanya Kalesi duvarlarının dominant bitki türlerdir. Bu bitkilerin kale duvarları üzerine taşınım yolları ve bitkilerle mücadele yöntemleri detaylı şekilde tartışılmıştır. Tarihi yapılarda doğal olarak yetişen ve bu yapılara zarar veren bitkilerle mücadelede en etkili yöntemin mekanik mücadele olduğu anlaşılmıştır.

Anahtar kelimeler: Alanya, biyoçeşitlilik, duvar florası, kentsel ekosistemler, mekanik mücadele.

1. Introduction

Alanya town is one of the oldest settlements in Antalya. Although the exact establishment date of the town is not known, the oldest known name of the city is Calanoros which meant "Güzel dağ'' in the Byzantium Period (A.D. 395-1453) [1]. Its name was later changed to Alaiye after the city was conquered by the Anatolian Seljuk Emperor 1. Allaaddin Keykubat. In 1935, the name of the city was finally changed to Alanya by Mustafa Kemal Atatürk [2]. Since Alanya hosted many civilisations and different cultures, the city has many cultural assets such as; Red Tower, Castle Walls, Seljuk Shipyard, Seljuk Armoury, Alanya Lantern, Hıdırellez Dede and Adem Atacağı [3].

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Although ferns, algae and flowering plants on historic buildings are considered to be additional ornamental plants and contribute to the completion of the architectural and historical perception of the buildings, many of the historical artefacts today are worn for various reasons [4]. Although the most important factors causing these damages are known to be climatic conditions and neglected maintenance, the negative effects of plants on historical structures cannot be ignored in long-term either [5]. The edaphic requirements of the plants are related to the amount of seeds produced and their dispersion patterns. Usable substrate volume, substrate type, moisture requirements for germination and reproduction play an important role among the edaphic preferences; seed lightness, seed morphology (pappus and wing), and seed dispersal types (e.g. anemophilic and zoophilic) are the main factors affecting the formation of wall flora [6].

Studies on the wall flora constitute a significant part of the urban ecosystems. In this sense, the first study on wall flora was conducted by Brishbeth (1948) in the USA. Later, similar floristic and ecological studies were carried out on plants growing on historical monuments in India, Greece, Italy, Brazil, China, and England [6-13]. With regard to Turkey, (on a regional scale), various studies were carried out in Istanbul [14-16] and Edirne [17] in the Marmara Region; İzmir [18] and Muğla [19] in the Aegean Region; Kayseri [20] and Niğde [21] in the Central Anatolia Region; Van [22] in the Eastern Anatolia Region; Gaziantep [23] and Şanlıurfa [24] in the Southeastern Anatolia Region, and Hatay [25, 26], Isparta [27] and Antalya [5,28,29,30] in the Mediterranean Region. According to the literature, so far more than 350 vascular plant species have been identified on walls of historical buildings from Turkey [31].

Based on the literature search, there is a published study on the flora of Alanya Castle and its surroundings [28]. Although 322 plant species were reported in this study, there is no information about the effects of plants on historical structures. Therefore, in this study, we focused on vascular plants of the walls of Alanya Castle, the abundance of the detected species and their location on the wall, as well as their negative effects on the walls and possible measures to minimize these effects.

2. Materials and methods

Alanya is a city located east of Antalya (Turkey) between 36.54 latitude and 32.00 longitude and is situated at an elevation of approximately 225 meters above sea level (Figure 1). The plant specimens were collected from the walls of Alanya Castle between March 2015 and November 2017 (Figure 2).

Collected specimens were thoroughly evaluated using the relevant literature for species identification. “Flora of Turkey and the East Aegean Islands” and its appendices were used for identification of the taxa assessed in the floristic analysis [32-34]. The life forms of plants were determined according to Raunkiaer’s system [35]. The threat categories of endemic plants were determined using the Red Book of Turkish Plants and IUCN 2017 [36,37]. Turkish plant names were written using The Plant List of Turkey (Vascular Plants) given by Güner et al. (2012) and also the relative abundance of each plant species was determined by using Braun-Blanquet [38,39]. Further, the position of the plants on the walls was noted during the field study.

Figure 1. Location of the study area

Figure 2. General views of Alanya Castle

3. Results

The floristic list of plant species found on the walls of Alanya Castle is given in Table 1.

Table 1. Floristic list of the Alanya Castle Walls (G: Geophyte, Th: Therophyte, H: Hemicryptophyte, Ch: Chamephyte, Ph: Phanerophyte), their relative abundance (1: Rare, 2: Occasional, 3: Frequent, 4: Codominant, 5: Dominant), and their position on the castle walls (V: Vertical, H: Horizontal).

Taxonomic categories and Families	**Species**	**Turkish Name**	**English Name**	**Life Form**	**Relative Abundance**	**Position (V/H)**
PTERIDOPHYTA		**Eğreltiler**	**Ferns**			
Aspleniaceae						
	Asplenium ceterach L.	Dalakotu	Rustyback	G.	3	V
Polypodiaceae						
	Polypodium vulgare L. var. *cambricum* (L.) Willd.	Benli eğrelti	Southern polypody	G.	2	V
Pteridaceae						
	Adiantum capillus-veneris L.	Baldırıkara	Maidenhair fern	H.	2	V
	Cheilanthes pteridioides (Reich.) C.Chr.	Kıvrık eğrelti	Hay-scented lip fern	H.	2	V
	Pteris vittata L.	Uzun eğrelti	Chinese ladder brake	H.	2	V
		AĞAÇLAR	**TREES**			
MAGNOLIOPHYTA MAGNOLIOPHYTINA		**Tohumlu Bitkiler Kapalı Tohumlu**	**Spermatophyta Angiospermae**			
Dicotyledonae		**Çift Çenekliler**	**Dicots**			
Moraceae						
	Ficus carica L. subsp. *carica*	İncir	Common fig	Ph.	3	V, H
		ÇALILAR	**SHRUBS**			
PINOPHYTINA		**Açık Tohumlu**	**Gymnospermae**			
Ephedraceae						
	Ephedra foeminea Forssk.	Borotu	Leafless ephedra	Ph.	3	V, H
MAGNOLIOPHYTINA		**Kapalı Tohumlu**	**Angiospermae**			
Dicotyledonae		**Çift Çenekliler**	**Dicots**			
Capparaceae						
	Capparis orientalis Veill.	Kabakarın	Caper- bush	Ph.	4	V
Vitaceae						
	Vitis sylvestris C.C.Gmel	Deli asma	Euroean wild grape	Ph.	2	V
		OTSULAR	**HERBS**			
Dicotyledonae		**Çift Çenekliler**	**Dicots**			

Taxonomic categories and Families	Species	Turkish Name	English Name	Life Form	Relative Abundance	Position (V/H)
Apiaceae						
	Eryngium glomeratum Lam	Top boğadikeni	Eryngo	H.	3	V, H
	Ferula tingitana L.	Kadıteresi	The giant tangier fennel	H.	4	H
Araliaceae						
	Hedera helix L.	Duvar sarmaşığı	English Ivy	Ph.	4	V
Asteraceae						
	Centaurea scopulorum Boiss. & Heldr var. *scopulorum*	Makberinaşkı	-	H.	2	V
	Conyza bonariensis (L.) Cronquist	Çakalotu	Argentine fleabane	Th.	4	V, H
	Conyza canadensis (L.) Cronquist	Selvi otu	Canadian horseweed	Th.	5	V, H
	Crepis sancta (L.) Bornm.	Yaban kıskısı	Hawksbeard	Th.	4	V, H
	Geropogon hybridus (L.) Sch. Bip.	Melez yemlik	Slender salsify	Th.	2	H
	Inula heterolepis Boiss.	Ak andızotu	Snow samphire	H.	5	V
	Lactuca serriola L.	Eşekhelvası	Prickly lettuce	H.	3	H
	Phagnalon graecum Boiss. & Heldr	Bozçalı	Eastern phagnalon	Ch.	5	V, H
	Senecio vernalis Waldst. & Kit.	Kanarya otu	Eastern groundsel	Th.	4	V, H
	Sonchus oleraceus L.	Kuzugevreği	Common sowthistle	H.	4	V, H
Boraginaceae						
	**Alkanna macrosiphon* Boiss. & Heldr.	Kalkan havacivası	-	H.	3	V
	Cynoglossum creticum Mill.	Pisiktetiği	Hound's-tongue	H.	3	H
	Onosma frutescens Lam.	Sarı emcek	Bushy golden-drop	H.	4	V, H
Brassicaceae						
	Arabis verna (L.) R.Br.	Mor kazteresi	Spring rockcress	Th.	5	V, H
	Biscutella didyma L.	Çıtçıtotu	Mediterranean Biscutella	Th.	2	V, H
	Cardamine hirsuta L.	Kıllı kodim	Hairy bittercress	Th.	2	V
	**Conringia grandiflora* Boiss. & Heldr.	İritelkari	-	Th.	3	V, H
	Lepidium draba L.	Diğnik	Hoary cress	H.	3	H
	Malcolmia chia (L.) DC.	Ekinteresi	Chian stock	Th.	3	V, H
	Ricotia carnosula Boiss.& Heldr.	Dişli cavlak	-	Th.	3	V, H
Campanulaceae						
	Campanula drabifolia Sibth. & Sm	Dişli çançiçeği	Bellflower	Th.	3	V
	Campanula erinus L.	Çatal çançiçeği	Elatine bellflower	Th.	2	V, H
	Campanula propinqua Fisch. & C.A.Mey	Kum çamı	Bellflower	Th.	2	V, H
Caprifoliaceae						
	Valeriana dioscoridis Sm.	Çobanzurnası	Italian valerian	H.	2	H
Caryophyllaceae						
	**Arenaria pamphylica* Boiss. & Heldr. subsp. *pamphylica* var. *pamphylica*	Kıyı kumotu	-	H.	3	V
	Arenaria serpyllifolia L. subsp. *serpyllifolia*	Tarla kumotu	Thymeleaf sandwort	H.	5	V
	Cerastium glomeratum Thuill.	Boynuzotu	Sticky chickweed	Th.	4	V, H
	Cerastium semidecandrum L.	Çengel boynuzotu	Little mouse-ear	Th.	3	V, H
	Dianthus elegans d Urv. *var. cous* **(**Boiss.) Reeve	Deli karanfil	Elegant pink	Ch.	3	V
	Dianthus strictus Banks & Sol. var. *strictus*	Dimisok	Wild carnation	Ch.	2	V, H
	Minuartia globulosa (Labill.) Schinz & Thell	Top tıstıs	-	Th.	3	V, H
	Minuartia hybrida (Vill.) Schischk.subsp. *hybrida*	Çayır tıstısı	Fine-leaved Sandwort	Th.	4	V, H
	Minuartia picta (Sibth. & Sm.) Bornm	Ergen tıstıs	Sandwort	Th.	4	V, H
	Polycarpon tetraphyllum (L.) L.	Kırkinciotu	Four-leaved allseed	Th.	2	V, H
	Silene dichotoma Ehrh. subsp. *dichotoma*	Çatal nakıl	Forked catchfly	H.	3	H
	Silene gigantea L. subsp. *gigantea*	Koca nakıl	-	H.	3	H

Taxonomic categories and Families	Species	Turkish Name	English Name	Life Form	Relative Abundance	Position (V/H)
	Silene sedoides Poir.	Yatık nakıl	Hairy catchfly	Th.	3	V
	**Velezia pseudorigida* Hub.-Mor.	Has tığotu	-	Th.	3	V, H
Crassulaceae						
	Rosularia globulariifolia (Fenzl) A.Berger	Top kayakoruğu	-	Ch	3	V
	Sedum caespitosum (Cav.) DC.	Bodur damkoruğu	Broad-leaved stonecrop	Th.	4	V
	Sedum sediforme (Jacq.) Pau	Yalı koruğu	Pale stonecrop	Ch.	4	V, H
	Umbilicus horizontalis DC.	Kalaba	Horizontal navelwort	Ch.	3	V, H
Euphorbiaceae						
	Mercurialis annua L.	Parşen	Annual mercury	Th.	5	H
Fabaceae						
	Lathyrus setifolius L.	Büllü baklası	Red pea	Th.	2	H
	Medicago polymorpha L. var. *polymorpha*	Kırkyonca	Bur clover	Th.	3	V
Geraniaceae						
	Erodium malacoides (L.) L Her.	Dönbaba	Mediterranean stork's bill	Th.	3	V, H
	Geranium lucidum L.	Dakkaotu	Shining cranesbill	Th.	3	V
	Geranium pusillum Burm.f.	İncegelinçarşafı	Small-flowered Crane's-bill	Th.	3	V
Hypericaceae						
	Hypericum perfoliatum L.	Binbirdelik otu	Saint John's wort	H.	3	H
	Hypericum triquetrifolium Turra	Pırpırotu	Wavy-leaf St John's wort	H.	3	H
Lamiaceae						
	**Ajuga bombycina* Boiss.	Geyik mayasılı	-	H.	3	V
	Clinopodium insulare (Candargy) Govaerts	Ada fesleğeni	-	H.	3	V, H
	Lamium amplexicaule L. var. *amplexicaule*	Baltutan	Henbit deadnettle	Th.	3	V
	Micromeria myrtifolia Boiss. & Hohen.	Boğumluçay	Cyprus wild savory	Ch.	4	H
	Teucrium polium L. subsp. *polium*	Acıyavşan	Felty germander	Ch.	4	V, H
Linaceae						
	Linum strictum L. var. *strictum*	Tok keten	Upright flax	Th.	4	H
Oxalidaceae						
	Oxalis pes-caprae L.	Koca ekşiyonca	Bermuda buttercup	G.	4	V, H
Papaveraceae						
	Fumaria parviflora Lam.	Tarla şahteresi	Fineleaf fumitory	Th.	5	H
	Glaucium flavum Crantz	Gündürmelalesi	Yellow horned poppy	Ch.	3	H
	Papaver rhoeas L.	Gelincik	Common poppy	Th.	3	H
Plantaginaceae						
	Cymbalaria microcalyx (Boiss.) Wettst.	Hoş nakkaşotu	Ivy leaved toad-flax	H.	5	V
	Veronica cymbalaria Bodard	Venüsçiçeği	Pale speedwell	Th.	4	V
	Veronica syriaca Roem. & Schult.	Arap mavişi	Syrian speedwell	Th.	3	V
Ranunculaceae						
	Clematis cirrhosa L.	Bahar sarmaşığı	Virgin's bower	Ph.	3	V
	Delphinium peregrinum L.	Tel hezaren	Violet larkspur	Th.	2	V
Rosaceae						
	Sanguisorba verrucosa (G.Don) Ces.	Sincanotu	Mediterranean salad burnet	H.	3	V
Rubiaceae						
	**Galium canum* Req. ex DC. subsp. *antalyense* Ehrend	Antalya yoğurtotu	-	Ch.	5	V
	Valantia hispida L.	Kıllı örenotu	Hairy valantia	Th.	5	V, H
Saxifragaceae						
	Saxifraga hederacea L.	Cılız taşkıran	-	Th.	4	V
Scrophulariaceae						
	Scrophularia pinardii Boiss.	Çalı sıracası	-	Ch.	4	V

Taxonomic categories and Families	Species	Turkish Name	English Name	Life Form	Relative Abundance	Position (V/H)
	Verbascum levanticum I.K. Ferguson	Arap sığırkuyruğu	Broad leaf mullein	H.	3	V, H
Solanaceae						
	Hyoscyamus aureus L.	Sarı banotu	Golden henbane	H.	5	V
Urticaceae						
	Parietaria cretica L.	Sırçaotu	Cretan pellitory	Th.	5	V
	Parietaria judaica L.	Duvar fesleğeni	Spreading pellitory	Th.	5	V
Monocotyledonae		**Tek Çenekliler**	**Monocots**			
Amaryllidaceae						
	Allium neapolitanum Cyr.	Sarımsak çiçeği	Neapolitan garlic	G.	3	V, H
Liliaceae						
	Gagea fibrosa (Desf.) Schult. & Schult.f.	Tellisarı	Yellow star-of-bethlehem	G.	3	H
Poaceae						
	Aegilops biuncialis Vis.	İkikılçık	Mediterranean aegilops	Th.	4	H
	Aegilops umbellulata Zhuk.	Hanım buğdayı	Goatgrass	Th.	4	H
	Briza maxima L.	Kuşyüreği	Big quaking grass	Th.	3	H
	Bromus rigidus Roth.	Sert brom	Ripgut brome	Th.	4	H
	Bromus sterilis L.	Sağır ilcan	Barren brome	Th.	4	H
	Poa bulbosa L.	Yumrulu salkım	Bulbous bluegrass	H.	5	H

* Endemic species

A total of 94 plant taxa, including five pteridophytes, one gymnosperm and 88 angiosperms, belonging to 35 families were identified on the walls of Alanya Castle (Table 1-2).

Table 2. Total numbers of families and taxa

Taxonomic Units	Total numbers of families	Total numbers of taxa	Numbers of endemic taxa
Pteridophyta	3	5	-
Gymnospermae	1	1	-
Angiospermae			
Dicotyledonae	28	80	6
Monocotyledonae	3	8	
Total	**35**	**94**	**6**

In the investigated area, Caryophyllaceae (14 species) was the richest family with 14 species (%14,9 of all detected species) followed by Asteraceae (10 species, %10,6), Brassicaceae (7 species, %7,4), Poaceae (6 species, %6,4), Lamiaceae (5 species, %5,3) and others (52 species, %53,23) (Figure 3).

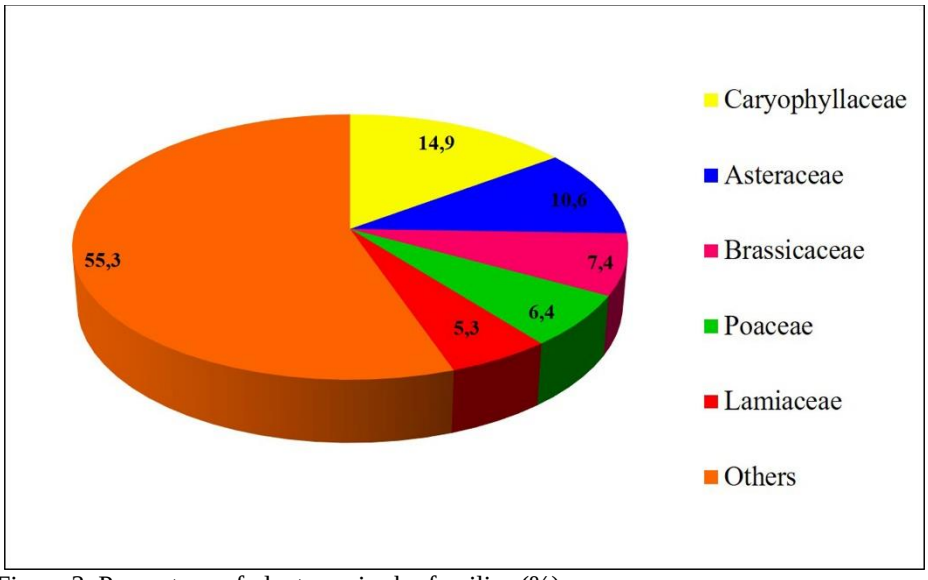

Figure 3. Percentage of plant species by families (%)

4. Discussion and conclusions

Conyza canadensis, Inula heterolepis, Phagnalon graecum, Arabis verna, Mercurialis annua, Fumaria parviflora, Cymbalaria microcalyx, Galium canum subsp. *antalyense, Parietaria judaica, Hyoscyamus aureus, Poa bulbosa* were the dominant plant species of Alanya Castle walls (Figure 4). These findings are similar to other studies conducted in the Mediterranean region [5,26,28,29]. The life forms of the plants were determined to be 47.8% therophytes, 28.7% hemicryptophytes, 11.7% chamephytes, 6.4% phanerophytes and 5.4% geophytes. Among them, six endemic taxa were found. Four of these endemics are considered to be of global conservation concern. *Arenaria pamphylica* subsp. *pamphylica* and *Velezia pseudorigida* are listed as Vulnerable (VU), and *Ajuga bombycina* and *Galium canum* subsp. *antalyense* are Near Threatened (NT) on the IUCN Red List Categories [36]. On the other hand, *Alkanna macrosiphon* and *Conringia grandiflora* are listed as Least Concern (LC) (Table 1).

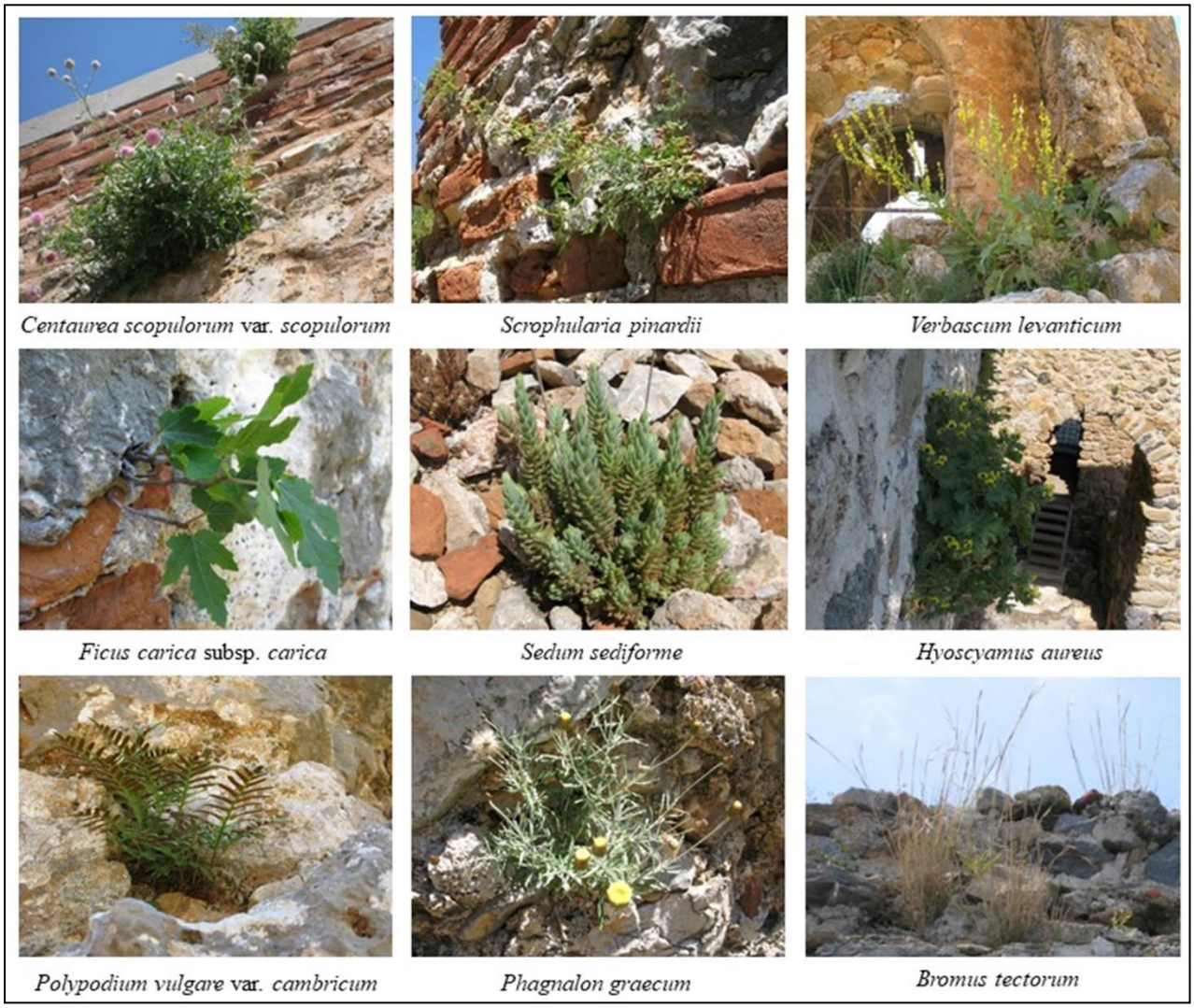

Figure 4. Some plant species that were found on the walls of Alanya Castle

It is possible to see one or more of the stages of succession in terrestrial ecosystems on historic structures. Many cyanobacteria, lichen and fungi species, especially on the exterior surfaces of buildings, are dark coloured. They often lead to aesthetic deterioration because they cause color loss of the surfaces during their growth phase. Moreover, some lichen species can cause active erosion on rocks of historic structures due to secreted (usnic acid) substances [40].

As the walls are located in urban and rural landscapes, they are highly influenced by the ornamental and natural vegetation types surrounding the composition of the wall flora [4]. For this reason, members of the cosmopolitan family of Asteraceae are frequently encountered on historical structures [14-16, 28]. The plant species such as *Conyza canadensis, Crepis sancta, Inula heterolepis, Sonchus oleraceus* were the most common on Alanya Castle walls. The most important reason of this frequent occurrence is that in this family seeds, which have, pappus and wing-like structures are distributed by wind [5, 6].

The castle walls form microhabitats with substrate located in spaces and cracks and thus shape the growth conditions of the plants [6]. Indeed, annual plants develop in these small spaces along the vertical surfaces of the walls. The most common annual plants on the vertical surface at the walls of Alanya Castle were *Arabis verna*, *Campanula drabifolia, Arenaria serpyllifolia, Cerastium glomeratum, Geranium lucidum, Sonchus oleraceus* and *Cymbalaria microcalyx.* At the same time, these micro-habitats also host endemic *Alkanna macrosiphon*, *Galium canum* subsp. *antalyense*, *Arenaria pamphylica* subsp. *pamphylica* (Table 1).

The accumulation of sediments in the cracks of the roofs and walls of the buildings allow the diaspores to settle and germinate. For this reason, it is possible to see the invasive species more in these parts of the castle. The most common species on the roofs of Alanya Castle were *Allium neapolitanum* and *Ferula tingitana*. Birds and ants play an important role in the transport of seeds over long distances [41, 42]. One of the main factor in seeing Poaceae members like *Aegilops umbellulata*, *Poa bulbosa*, and *Briza maxima* on the roofs of historical buildings may include these animals.

We detected plants that were bushes with tap root systems such as *Capparis spinosa*, *Ficus carica*, and *Hedera helix* on bottom and top parts of the historical walls. These species move the rocks forming the castle walls due to their root system and cause the destruction of the historical structure. Also, if no precautions are taken, parts of the Alanya Castle walls may potentially fall over people causing serious damage.

Studies on controlling growth and occurrence of plants that destroy historical buildings are limited. Physical (flame), chemical (glyphosate active herbicide), and mechanical (cutting and dismounting) control methods could be used to control these plants. No information has been encountered regarding the use of the flaming method against plants growing on historical buildings, neither in the world nor in our country. Although this method would be easily applicable and is estimated to be successful in plant control, it should not be preferred due to the bad appearance of burn marks it would leave on the wall surface. While herbicide applications make it possible to get fast results in the short term, the chemicals they contain can cause abrasions on the wall surface. In addition, herbicide applications bear some difficulties such as the problem of using different (and the right) dosages for each plant species, being costly and requiring specialists for application. With regard to the limitations of the above mentioned methods, a mechanical approach (for example digging, cutting, excavation) seems to be more preferable. It would not leave any visible marks to the walls and would not require the use of chemicals. However, it may not give good results in removing plants with tap root systems because during their removal the filling materials between the wall stones might be damaged and cause the stones to move. Therefore, applying mechanical control method in the early development phase of plants will cause less damage to historical buildings [29].

As described above, we believe that the most effective method in the light of this data is still the mechanical controlling method. Although it might not be possible to deal with the plants on the historical buildings entirely, the occurrence and growth of plants could be diminished and the damage they cause could be significantly reduced. With this method, the Alanya Castle which is one of our historical heritage could be preserved and ensured that its presence continues for many years.

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