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

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.
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                     | Asplenium ceterach L. | Dalakotu | Rustyback | G. | 3 | V |
| Polypodiaceae                    | Polypodium vulgare L. var. cambricum (L.) Willd. | Benli eğrelti | Southern polyody | G. | 2 | V |
| Pteridaceae                      | Adiantum capillus-veneris L. | Baldırıkara | Maidenhair fern | H. | 2 | V |
|                                 | Chelianthes pteridioides (Reich.) C.Chr. | Kivrık eğrelti | Hay-scented fern | H. | 2 | V |
|                                 | Pteris vittata L. | Uzun eğrelti | Chinese brake | H. | 2 | V |
| AGACLAR                           | Magnoliophyta | Tohumlu Bitkiler | Spermatophyta | Angiospermae | Dicotyledoneae | Çift Çenekiller | Dicots |
| MAGNOLIOPHYTINA                  | Capparaceae | Ficus carica L. subsp. carica | Incir | Common fig | Ph. | 3 | V, H |
| DICILBAR                          | Ephedraceae | Ephedra foeminea Forssk. | Borotu | Leafless ephedra | Ph. | 3 | V, H |
| CALILAR                           | Magnoliophyta | Caprifoliaceae | Capparis orientalis Veill. | Kabakarn | Caper-bush | Ph. | 4 | V |
| PINOPHYTINA                       | Vitaceae | Vitis vinifera C.C.Gmel | Deli asma | European wild grape | Ph. | 2 | V |
| OTSULAR                           | Dicotyledoneae | | | | | |
| Taxonomic categories and Families | Species | Turkish Name | English Name | Life Form | Relative Abundance | Position (V/H) |
|----------------------------------|---------|--------------|--------------|-----------|-------------------|----------------|
| Apiaceae                         | Eryngium glomeratum Lam | Top boğazdikeni | Eryngo | H. | 3 | V, H |
| Foeniculum vulgare L. | Kadisteresi | The giant tangier fennel | H. | 4 | H |
| Arajaceae                        | Hedera helix L. | Duvar sarması | English Ivy | Ph. | 4 | V |
| Asteraceae                       | Centaurea scopolium Boiss. & Heldr. var. scopolorum | Makberınışığı | - | H. | 2 | V |
| Conyza bonariensis (L.) Cronquist | Çakanalotu | Argentine fleabane | Th. | 4 | V, H |
| Conyza canadensis (L.) Cronquist | Selvi otu | Canadian horseweed | Th. | 5 | V, H |
| Crepis sancto (L.) Bornm. | Yaban kuskusu | Hawksbeard | Th. | 4 | V, H |
| Geropogon hybrida (L.) Sch. Bip. | Melez yemlik | Slender salsify | Th. | 2 | H |
| Inula heterolepis Boiss. | Ak andızotu | Snow samphire | H. | 5 | V |
| Lactuca serriola L. | Eğekhelvası | Prickly lettuce | H. | 3 | H |
| Phagnalon graecum Boiss. & Heldr | Boçaklı | Eastern phagnalon | Ch. | 5 | V, H |
| Senecio vernalis Waldst. & Kit. | Kanarya otu | Eastern groundsel | Th. | 4 | V, H |
| Sonchus oleraceus L. | Kuzugevregi | Common sowthistle | H. | 4 | V, H |
| Boraginaceae                     | *Alkanna macrosephlon Boiss. & Heldr. | Kalkan havacivası | - | H. | 3 | V |
| Cyanoglossum creticum Mill. | Pıniketiği | 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 kazieresu | Spring rockcress | Th. | 5 | V, H |
| Biscutella didyma L. | Çiçëtötu | Mediterranean Biscutella | Th. | 2 | H |
| Cardamine hirsuta L. | Kılı kodımı | Hairy bittercress | Th. | 2 | V |
| *Convingia grandiflora Boiss. & Heldr. | İrielikari | - | Th. | 3 | V, H |
| Lepidium draba L. | Diğnik | Hoary cress | H. | 3 | H |
| Malcolmia chia (L.) DC. | Ekinteresi | Chian stock | Th. | 3 | V, H |
| Ricotta carnosula Boiss. & Heldr. | Dişli cavıklak | - | Th. | 3 | V, H |
| Campanulaceae                    | Campanula drahfolia Sibth. & Sm | Dişli çançiceği | Bellflower | Th. | 3 | V |
| Campanula erinus L. | Çatal çançiceği | Elatine bellflower | Th. | 2 | V, H |
| Campanula propinqua Fisch. & C.A.Mey | Kum çamı | Bellflower | Th. | 2 | V, H |
| Caprifoliaceae                   | Valeriana dioecorda Sm. | Çobanzurnası | Italian valerian | H. | 2 | H |
| Caryophyllaceae                  | *Arenaria pamphylica Boiss. & Heldr. subsp. pamphylica var. pamphylica | Kys kumotu | - | H. | 3 | V |
| Arenaria serpyllifolia L. subsp. serpyllifolia | Tarla kumotu | Thymeleaf sandwort | H. | 5 | V |
| Cerasitum glomeratum Thun. | Boyunuzotu | Sticky chickweed | Th. | 4 | V, H |
| Cerasitum semidecandrum L. | Çengel boynuzotu | Little mouse-ear | Th. | 3 | V, H |
| Dianthus elegans d Urv. var. coas (Boiss.) Reeve | Deli karanfil | Elegant pink | Ch. | 3 | V |
| Dianthus strictus Banks & Sol. var. strictus | Dimisok | Wild carnation | Ch. | 2 | V |
| Minuartia globulosa (Labiill.) Schinz & Thell | Top tists | - | Th. | 3 | V, H |
| Minuartia hybrida (Vill.) Schischk. subsp. hybrida | Çayır tistsı | Fine-leaved Sandwort | Th. | 4 | V, H |
| Minuartia picta (Sibth. & Sm.) Bornm. | Ergen tistsı | Sandwort | Th. | 4 | V, H |
| Polycarpum tetraphyllum (L.) L. | Kerkincıcotu | Four-leaved aliseed | Th. | 2 | V, H |
| Silene dichotoma Ehrh. subsp. dichotoma | Çatal nakil | Forked catchfly | H. | 3 | H |
| Silene gigantea gigantea L. subsp. Koca nakil | - | - | 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 globularifolia (Fenzl) A.Berger | Top kayakoruğu | - | Ch | 3 | V |
| Sedum caespitosum (Cav.) DC.     | Bodur damkorğu | Broad-leaved stonecrop | Th. | 4 | V |
| Sedum sediforme (Jacq.) Pau      | Yali 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. | Bilüli baklası | Red pea | Th. | 2 | H |
|                               | Medicago polymorpha L. var. polymorpha | Kurkyonca | 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 Cran'e-bill | Th. | 3 | V |
| Hypericaceae                     | Hypericum perforliatum L. | Bambahdelik otu | Saint John's wort | H. | 3 | H |
|                               | Hypericum triquetrifolium Turra | Papprotu | Wavy-leaf St John's wort | H. | 3 | H |
| Lamiaeae                         | *Ajuga bombycina* Boiss. | Geyik mayasılı | - | H. | 3 | V |
|                               | Clinopodium insulare (Candargy) Govaerts | Ada fesleğeni | - | H. | 3 | V, H |
|                               | Lamium amplexicaule L. var. amplexicaule | Balstin | Henbit deadnettle | Th. | 3 | V |
|                               | Micromeria myrtifolia Boiss. & Hohen. | Boğumulçay | 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 sahteresi | Fineleaf fumitory | Th. | 5 | H |
|                               | Glaucom flavum Crantz | Gündürmelalesi | Yellow horned poppy | Ch. | 3 | H |
|                               | Papaver rhoeas L. | Gelincik | Common poppy | Th. | 3 | H |
| Plantaginaceae                   | Cymbalaria microalyx (Boiss.) Wettst. | Hoş nakkaşotu | Ivy leaved toad-flax | H. | 5 | V |
|                               | Veronica cymbalaria Bodard | Venüşüççüğü | Pale speedwell | Th. | 4 | V |
|                               | Veronica syriaca Roem. & Schult. | Arap mavışı | Syrian speedwell | Th. | 3 | V |
| Ranunculaceae                    | Clematis cirrhosa L. | Bahar sarmaşı | 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 yoğunrotu | - | Ch. | 5 | V |
|                               | Valantia hispida L. | Kılı şirenotu | Hairy valantia | Th. | 5 | V, H |
| Saxifragaceae                    | Saxifraga hederacea L. | Çalı taşkıran | - | Th. | 4 | V |
| Scrophulariaceae                 | Serophularia pinardii Boiss. | Çalı sıracası | - | Ch. | 4 | V |

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## Taxonomic categories and Families

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### Table 1

| Species                             | Turkish Name            | English Name               | Life Form | Relative Abundance | Position (V/H) |
|-------------------------------------|-------------------------|---------------------------|-----------|--------------------|----------------|
| Verbascum levanticum                | İ.K. Ferguson           | Arap sağırkuyruğu          | H.        | 3                  | V, H           |
| Hyoscyamus aureus L.                | Sarı banotu             | Golden henbane            | H.        | 5                  | V              |
| Parietaria cretica L.               | Sarçacu                  | Cretan pellitory           | Th.       | 5                  | V              |
| Parietaria judaica L.               | Doğar feseleği           | Spreading pellitory        | Th.       | 5                  | V              |

### 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% hemicyryptophytes, 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*, *Sonnichs 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 flame (flame), chemical (glyphosate active herbicide) 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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