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Full Paper

Urban ecological characteristics and vascular wall flora on the Anatolian side of Istanbul, Turkey

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Abstract: The aim of this study is to specify the urban ecologic characteristics of Istanbul and to show their reflection to the vascular wall flora of the Anatolian side, which is a distinctive wall habitat. Plants samples of the urban habitat were collected from the top and vertical surfaces of walls during 2005-2007. A total of 101 taxa (81 species, 13 subspecies and 7 varieties) belonging to 74 genera and 33 families were recorded. It was determined that 80 species were Dicotyledones while 1 was Monocotyledone. The families with the largest number of taxa were Asteraceae (18 species, 22.22%), Poaceae (8 species, 9.87%), Lamiaceae and Brassicaceae (5 species, 6.17%), and Polygonaceae and Scrophulariaceae (4 species, 4.93%). The most common plant species on walls were *Parietaria judaica* L. (Urticaceae), *Stellaria media* (L.) Vill. subsp. *media* (Caryophyllaceae), and *Mercurialis annua* L. (Euphorbiaceae). The percentage of phytogeographical elements among the recorded taxa varied as follows: Euro-Siberian (6 taxa, 7.41%), Mediterranean (11 taxa, 13.58%), E. Mediterranian (2 taxa, 2.47%), Irano-Turanian (1 taxon, 1.23%) and unknown (61 taxa, 75.31%). It was found that 6 taxa (7.41%) were cosmopolitan, 12 (14.82%) were widespread while 1 (1.23%) was endemic. The results were compared with some other European wall floras and some similarities and dissimilarities were noted.

Keywords: vascular wall flora, Istanbul, urban habitat, urban ecology

INTRODUCTION

Istanbul is one of the most populous cities of Eurasia and is the world's 4th largest city proper and 20th largest urban area as well as Turkey's cultural and financial centre. The city is located in the

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NW part of Turkey (41° 01.2' N, 28° 58.2' E) and it extends both on European (Thrace) and Asian (Anatolia) sides of the Bosphorus. It is the only metropolis in the world which is situated on two continents [1-5]. Its neighbours are the Black Sea in the north, Marmara Sea in the south, Kocaeli City in the east, and Tekirdağ City in the west (Figure 1). Istanbul has approximately 5100 km^2 of land area and 12,573,836 population. In its long history, Istanbul served as a capital city of the Roman Empire (AD 330-395), Byzantine Empire (AD 395-1204 and AD1261-1453), Latin Empire (AD 1204-1261), and Ottoman Empire (AD 1453-1922) [3, 6]. In addition to its rich history, high population and productive economy, Istanbul also has a wide variety of ecological features [3].

Figure 1. Districts studied in Istanbul during 2005-2007 (Beykoz, Üsküdar, Kadıköy, Kartal, Ümraniye, Maltepe, Tuzla, Pendik, Adalar and Sultanbeyli)

The main topographical feature of Istanbul is a low plateau at about 100-200 m elevation where there are many hills and a few streams in the city. The geological structure of Istanbul is diverse with Silurian, Devonian, Carboniferous, and Tertiary formations. There are different kinds of rocks including granitic plutons, quartzes, grovacs, clayed schsists and radiolarites [2, 7].

In Istanbul, many different types of soils are present while brown forest soil covers the most area. Non-calcareous brown soil is the second and is kind of soil is suitable for plant growth as a result of organic matter. The rendzinas, which cover especially the European side of the city, are also important. In addition, alluvial soil is also present [2, 7].

Istanbul is in a kind of transition zone between less rainy Mediterranean and oceanic climates. In the summer, less precipitation and high temperature are characteristic and the annual mean temperature is 14.5^{o}C for the last two decades. Between May and September the temperature is

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generally above 30°C and between November and April it is rarely below 0°C. In the vegetation period, the daily mean temperature is approximately 8°C, which lasts for about 280 days (between 15 March and 20 December) [2-5, 8].

The total precipitation for Istanbul averages 640 mm per year and 40% of the total precipitation falls in winter. December and January are the wettest months. Precipitation in summer is more than the typical Mediterranean situation and is more related to the oceanic climate. The minimal amount of rain falls (about 8%) in July and August. Precipitation is less in spring (about 20-21%) while it increases in autumn (about 28-29%), and snow rarely falls in Istanbul. The rain regime is Winter-Autumn-Spring-Summer (W.A.Sp.Su) and the rain type is "Central Mediterranean Rain Type" [2, 9].

The relative humidity is between 73-77% in the city and these values decrease to 65-68% in the summer despite the effect of the seas. The lower relative humidity, especially in the dry period, forms xerophytic vegetation. The dominant wind in the city is from the NE [8-9].

The wide variety of ecological features in Istanbul have resulted in more Pteridophyta and Angiospermae (2500 species) than those in England (250,000 km^2 land area, 1850 plant species) and Netherlands (50,000 km^2 land area, 1600 species) [10]. Istanbul's rich flora has been studied by many botanists due to its varied climatic and geographic conditions. Many floristic studies in urban and rural areas have been done in Turkey [7, 11-13]. Aksoy [14-15] carried out some studies on the green areas in Istanbul while others have done urban ecological studies, i.e. Şahin [16] in Eminönü and Fatih, Altay et al. [3] in Kartal, Osma et al. [4] in Kadıköy, Mutlu [17] in Üsküdar, and Eskin [18] in Pendik districts.

Buildings and all types of walls are urban features represent a specific environment [19-20]. The colonisation of plants on walls is favoured by the wall ages, the presence of lime mortar, exposure to rain, and such aspects as south and verticality. Most true wall species are only found on vertical walls and as the angle of inclination decreases an ever-widening range of common species colonise [21]. The wall habitat is different from natural habitat and rocks, depending on many different properties related to wall structures. Buildings contain binding materials, which structurally and chemically differ from the original building materials. Usually most of them are cleaned repeatedly; thus, they basically are temporary habitat. Walls are generally isolated, small, and their microclimate is more affected by changes of climatic factors such as temperature, precipitation and irradiation than that of rocks. Wall surfaces resemble each other and have a uniform slope (generally right-angled) and microtopographical characteristic with few microhabitats. Walls are located both in urban and rural areas, so wall flora is influenced by the nearby ruderal and semi-natural vegetation [22].

Wall flora which shows differences from urban and rural flora has attracted many botanists in different countries and cities. Comparison of wall vegetation in southern, western and central Europe was done by Segal [23] and Brandes [24-25]. Carmona et al.[26] in Spain, Hruska [27] in Italy, Gehu [28] in France, Woodell [19] in England, Oberdorfer [29] in Germany, Weretelnik [30] in Poland, Mucina [31] in Austria, Valachovic and Maglocky [32] in Slovakia, Duchoslav [22] in the Czech Republic, and Pavlova and Tonkov [20] in Bulgaria have studied wall flora.

Wall flora studies in Turkey are limited and include those by Gemici et al. [33] in İzmir, Aksoy and Çelik [34] in Kayseri, Yeşilot [35] in Istanbul European side, and Yarcı and Özçelik [36] in Edirne. These studies were mostly on walls of historical buildings.

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Our study was carried out in all districts of the Anatolian side of Istanbul, excluding Şile, during 2005-2007 vegetation periods. This study was made on walls of historical buildings as well as those of gardens, houses, hospitals, schools, campuses, train stations and ateliers, and especially on drain walls.

MATERIALS AND METHODS

The wall vascular flora on the Anatolian side of Istanbul was studied. Bryophyta and ornamental plants were not collected. Plant specimens were identified by using the "Flora of Turkey and the East Aegean Islands Volumes I-XI and Supp." [37] and were deposited in MÜFE Herbarium (Marmara University, Sciences and Arts Faculty Herbarium). The flora is listed alphabetically in the Appendix according to family, genera and species. Life forms [phanerophytes (Ph); chaemaphytes (Ch); hemicryptophytes (H); therophytes (Th); geophytes (G)] and phytogeographical origins [Euro-Siberian (Euro.-Sib.), Irano-Turanian (Ir.-Tur.), Mediterranean (Medit.), East Mediterranean (E. Medit.)] are included and were determined according to the Raunkier system [38-39].

RESULTS AND DISCUSSION

The total number of vascular plants growing spontaneously on walls included 101 taxa with 33 families and 74 genera (81 species, 13 subspecies and 7 varieties). Eighty species were Dicotyledones with one monocotyledon species (Table 1).

Table 1. Summary of collecting

	Monocotyledones		**Dicotyledones**		
Taxon	Number	%	Number	%	Total Number
Family	1	3.04	32	96.96	33
Genus	1	1.36	73	98.64	74
Species	1	1.24	80	98.76	81

There was only one monocotyledon species, *Asparagus acutifolius* L. (Liliaceae), which consisted of 1.24% of all species, while Dicotyledones were the prevalent group with 98.76% of all species. The following families were represented by the largest number of species: Asteraceae (18 species, 22.22%), Poaceae (8 species, 9.87%), Lamiaceae (5 species, 6.17%), Brassicaceae (5 species, 6.17%), Polygonaceae (4 species, 4.93%) and Scrophulariaceae (4 species, 4.93%) (Table 2). Although Asteraceae was the most common family, it had the lowest species/genus ratio (1.0). The same ratio was also for Brassicaceae, although it was a low-taxa family in this study. This ratio was higher in Polygonaceae (2.0), Scrophulariaceae (1.33), Lamiaceae (1.25) and Poaceae (1.14).

Previous studies noted that Asteraceae species have a species richness compared with other families [3-4, 20, 22, 24, 40-44]. Pavlova and Tonkov [20] also observed that Asteraceae was high in number of species in Central Europe, demonstrating the remarkable success of this family in terms of dispersal and establishment. Davis [37] also mentioned that Asteraceae represents highest number of

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species in the flora of Turkey. Other researchers obtained similar results with other families [20, 35-36].

Table 2. Genera and species numbers of the richest families

	Genera		Species		
Family	Number	%	Number	%	Species/Genus ratio
Asteraceae	18	24.32	18	22.22	1
Poaceae	7	9.45	8	9.87	1.14
Lamiaceae	4	5.40	5	6.17	1.25
Brassicaceae	5	6.75	5	6.17	1
Polygonaceae	2	2.70	4	4.93	2
Scrophulariaceae	3	4.05	4	4.93	1.33

In this study, life forms were determined according to the Raunkier system [38] and the largest groups were therophytes (45.72%) and hemicryptopytes (37.00%) (Figure 2). The patterns of these two life forms found on walls were similar to walls in Europe [18, 20-22]. In our study, percentages of other life forms were as follows: chamaephytes (2.46%), geophytes (4.94%) and phanerophytes (9.88%). Therophytes and hemicryptopytes are widespread in areas with a Mediterranean climate [3-4].

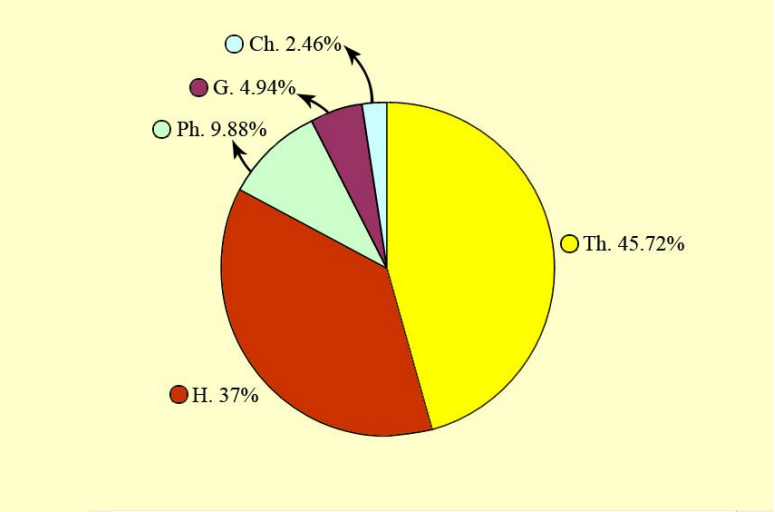

Figure 2. Pie diagram of the prevalence of life forms (H. = hemicryptophytes; Ph. = phanerophytes; G. = geophytes; Ch. = chaemaphytes; Th. = therophytes)

The most common phytogeographical elements were Mediterranean (13.58%) and Euro-Siberian elements (7.41%) (Figure 3). This is because Istanbul has a mostly Mediterranean climate.

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The northern side of Istanbul is partly affected by the oceanic climate [14]. Our study showed that six taxa (7.41%) were cosmopolitan and 12 taxa (14.82%) were widespread. Only one endemic taxon was found in our study. The most common plant species on walls were: *Parietaria judaica* L. (Urticaceae), *Stellaria media* (L.) Vill. subsp. *media* (Caryophyllaceae) and *Mercurialis annua* L. (Euphorbiaceae). We did not find any pteridophytes although in Central Europe and in the Mediterranean area they are present.

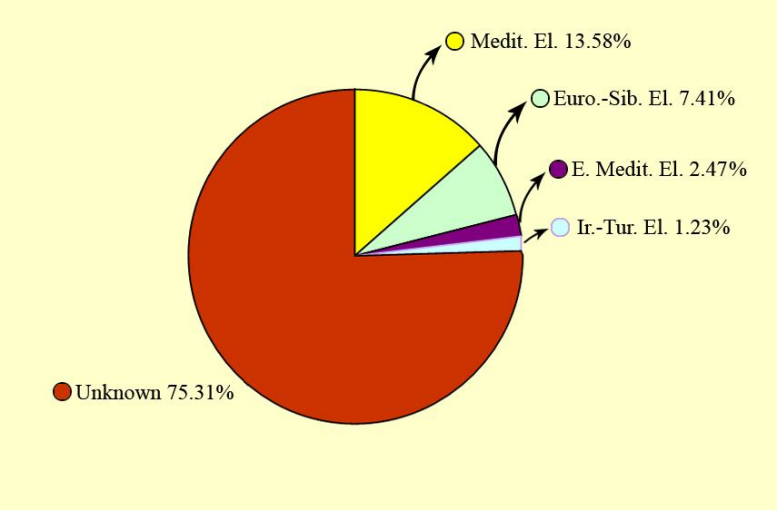

Figure 3. Pie diagram of the phytogeographical origins of the wall flora (Medit. El. = Mediterranean elements, Euro.-Sib. El. = Euro-Siberian elements, E. Medit. El. = East Mediterranean elements, Ir.-Tur. El. = Irano-Turanian elements)

We also found some archaeophyte and neophyte plants. An archaeophyte is not native to the geographical region, but was introduced in "ancient" times rather than during modern times. A neophyte has been recently introduced to the area. Archaeophytes are considered to be those species first introduced prior to 1500 AD while neophytes came after 1500 AD [45-46]. Archaeophyte and neophyte plants are listed in Table 3.

Plants growing on walls reach these habitats by wind (anemochorous), animals (zoochorous), mostly by birds and by stolon fragments (autochorous) [22, 36], and grow there randomly. Deep-rooted plants can be destructive. Although their roots are weak at the beginning of growth, they become stronger in time and cause widening of cracks. Most of these plants absorb little water from the substrate, but absorb it from the air [36]. Although wall plants are often aesthetically appealing, the local municipalities occasionally clean up the walls to prevent damage by the plants. It would be more preferable if the clean-up was more selective by allowing for plant type and degree of damage.

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Table 3. Archaeophyte and neophyte plants

Archaeophytes (before 1500 AD)	**Neophytes (after 1500 AD)**
Lamium purpureum L. (Lamiaceae)	*Conyza canadensis* (L.) Cronquist (Asteraceae)
Lamium amplexicaule L.	*Veronica persica* Poiret (Scrophulariaceae)
Euphorbia helioscopia L. (Euphorbiaceae)	*Cymbalaria muralis* Gaertner
Euphorbia peplus L.	*Ailanthus altissima* (Miller) Swingle (Simaroubaceae)
Sinapis arvensis L. (Brassicaceae)	*Oxalis corniculata* L. (Oxalidaceae)
Capsella bursapastoris (L.) Medik.	*Diplotaxis tenuifolia* (L.) DC. (Brassicaceae)
Fumaria officinalis L. (Papaveraceae)	
Stellaria media (L.) Vill. (Caryophyllaceae)	
Cerastium glomeratum Thuill	
Cichorium intybus L. (Asteraceae)	
Solanum nigrum L. (Solanaceae)	
Chenopodium album L. (Chenopodiaceae)	
Setaria viridis (L.) P. Beauv. (Poaceae)	

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APPENDIX (Flora List)

(Abbreviations: Ph = phanerophytes; Ch = chaemaphytes; H = hemicryptophytes; Th = therophytes; G = geophytes; Euro.-Sib. = Euro-Siberian; Ir.-Tur. = Irano-Turanian; Medit. = Mediterranean; E. Medit. = East Mediterranean; cos. = cosmopolitan; wid. = widespread; end. = endemic)

ANACARDIACEAE
Pistacia terebinthus L. subsp. *terebinthus* Ph, Medit.

APIACEAE
Conium maculatum L. H

ARALIACEAE
Hedera helix L. Ph

ASTERACEAE
Anthemis cretica L. H
Calendula arvensis L. Th
Carlina corymbosa L. H, Medit.
Centaurea solstitialis L. subsp. *solstitialis* H, wid.
Cichorium intybus L. Ch, wid.
Cirsium creticum (Lam.) d'Urv. subsp. *creticum* H, E. Medit.
Conyza canadensis L. Th
Erigeron acer L. H
Helminthotheca echioides (L.) Holup Th.
Hypochoeris radicata L. H, Euro.- Sib.
Inula viscosa (L.) Ailton H, Medit.
Lactuca saligna L. Th
Pallenis spinosa (L.) Cass. Th, Medit.
Picris strigosa Bieb. H, Ir.- Tur.
Senecio vulgaris L. Th
Sonchus asper (L.) Hill subsp. *glaucescens* (Jordan) Ball H, wid.
Taraxacum officinale Wiggers Ch
Tussilago farfara L. G, Euro.- Sib.

BRASSICACEAE
Capsella bursa-pastoris (L.) Medik. Th, cos.
Diplotaxis tenuifolia (L.) DC. H
Lepidium graminifolium L. H
Neslia apiculata Fisch. Th, wid.
Sinapis arvensis L. Th, wid.

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CAMPANULACEAE
Campanula lyrata Lam. subsp. *lyrata* H, wid., end.

CARYOPHYLLACEAE
Cerastium glomeratum Thuill Th, cos.
Stellaria media (L.) Vill. subsp. *media* Th
Telephium imperati L. subsp. *orientale* (Boiss.) Nyman H

CHENOPODIACEAE
Chenopodium album L. subsp. *album* var. *album* Th

CONVOLVULACEAE
Convolvulus arvensis L. H, cos.

CUCURBITACEAE
Ecballium elaterium (L.) A. Rich. H, Medit.

DIPSACACEAE
Scabiosa columbaria L. subsp. *columbaria* var. *columbaria* H

EUPHORBIACEAE
Euphorbia helioscopia L. Th
E. peplus L. var. *peplus* Th
Mercurialis annua L. Th

FABACEAE
Vicia hybrida L. Th

GERANIACEAE
Geranium purpureum Vill. Th

LAMIACEAE
Ajuga chamaepitys (L.) Schreber H
Calamintha nepeta (L.) Savi H
Lamium amplexicaule L. Th, Wid., Euro.- Sib.
Lamium purpureum L. var. *purpureum* Th, Euro.- Sib.
Micromeria graeca L. subsp. *graeca* H, Medit.

LILIACEAE
Asparagus acutifolius L. G, Medit.

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MALVACEAE
Malva sylestris L. H

MORACEAE
Ficus carica L. subsp. *carica* Ph, wid.

OLEACEAE
Ligustrum vulgare L. Ph, Euro.- Sib.
Phillyrea latifolia L. Ph, Medit.

OXALIDACEAE
Oxalis corniculata L. Th, cos.

PAPAVERACEAE
Fumaria officinalis L. Th
Glaucium flavum Crantz H
Papaver dubium L. Th

PLANTAGINACEAE
Plantago coronopus L. Th, Euro.- Sib.
P. lagopus L. Th, Medit.

POACEAE
Agrostis capillaris L. var. *capillaris* H
Bromus sterilis L. Th
Cynodon dactylon (L.) Pers var. *dactylon* G
Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman H
Hordeum murinum L. Th
Poa annua L. Th
Setaria viridis (L.) P. Beauv. Th, wid.
Setaria verticillata (L.) P. Beauv. Th

POLYGONACEAE
Polygonum aviculare L. Th, cos.
Polygonum lapathifolium L. Th.
Rumex conglomeratus Murray H
Rumex pulcher L. H

RESEDACEAE
Reseda lutea L. var. *lutea* H

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ROSACEAE
Rubus canescens DC. var. *canescens* Ph, wid.
Sarcopoterium spinosum (L.) Spach H, E. Medit.

RUBIACEAE
Galium aparine L. Th

SCROPHULARIACEAE
Antirrhinum majus L. subsp. *majus* H
Cymbalaria muralis Gaerth. Th, Medit.
Veronica cymbalaria Bodara Th, Medit.
Veronica persica Poiret Th

SIMAROUBACEAE
Ailanthus altissima (Miller) Swingle Ph

SOLANACEAE
Hyocyamus niger L. Th, wid.
Solanum nigrum L. subsp. *nigrum* Th, cos.

URTICACEAE
Parietaria judaica L. H, wid.

VALERIANACEAE
Centranthus ruber (L.) DC. G

VITACEAE
Vitis vinifera L. Ph

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