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The Bryophyte Flora of Ancient Cities of Aydın Province (Turkey)

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ABSTRACT: The bryophyte flora of ancient cities in Aydın province has been studied. Out of 450 bryophyte samples, a total of 130 moss taxa (belonging to 18 families and 47 genera) and 16 liverwort taxa (belonging to 10 families and 13 genera) were identified. Five of those moss taxa, namely *Fissidens fontanus, Crossidium aberrans*, *Didymodon bistratosus*, *Didymodon icmadophylus* and *Orthotrichum shawii*, are identified from the study area as the second records for the taxa in Turkey.

Key words: Bryophyte, Flora, Ancient Cities, Aydın, Turkey.

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INTRODUCTION

Turkey is one of the richest countries in the middle latitudes in terms of plant diversity, mainly due to its climate, geomorphic and soil diversity, and its situation at the junction of three important floristic regions (Euro-Siberian, Mediterranean and Irano-Turanian) (Avci 2005). Since 1829, approximately 250 studies have been carried out on Turkish bryoflora. Although over 950 bryophyte taxa have been identified so far (Kürschner & Erdağ 2005), it has been asserted that the total number of Turkish bryophyta might exceed this number. The research area is situated within the square designated as C11 according to the grid system of Turkey adopted by Henderson (1961). C11 is one of the squares that has been studied intensively for bryological flora in Turkey. Until the present time, 377 moss taxa (belonging to 37 families and 123 genera), 70 liverworts (belonging to 27 families and 32 genera) and 3 hornworts (belonging to only one family and 3 genera) have been identified from grid square C11 (unpublished data). In spite of the numerous studies on this, a number of new records are still emerging from this square (e.g. Kirmaci *et al*. 2009; Blockeel *et al.* 2009).

Aydın is one of the major provinces in the Aegean region of Turkey, located between 37^0 59′ N, 27^0 45′ E and 37^0 43′ N, 28^0 02′ E. It is divided by the İzmir - Aydın – Denizli highway and surrounded by Aydın Mountains to the North, the Aegean Sea to the West, Denizli to the East, Muğla to the Southwest and İzmir to the Northwest. Throughout history, Aydin province has hosted a great number of different civilizations and cultures. According to numerous archaeological studies previously carried out in Aydin Province, it is claimed that there are over 150 ancient cities (Anonymous 2012). However, most of them are still waiting to be explored. In this research, the biggest and most well-known ancient cities in Aydin province were studied (Figure 1).

The study area is under the influence of the Mediterranean climate. Thus, mean annual air temperature is 17.1^{0}C. Average temperature in January is 4.1 ^{0}C, while in July it is 34.8 ^{0}C. Mean annual relative humidity is 62.08 %. Mean annual precipitation is 672.7 mm and 70 % of it comes in the winter period. Dominant wind direction is westward (Anonymous 2006). The major vegetation types in different localities of the study area are represented by destroyed maquis elements such as *Quercus coccifera* L., *Pistacia lentiscus* L., *Ceratonia siliqua* L., *Styrax officinalis* L. and *Pinus brutia* Ten., which remain standing after fire and cutting down. In addition to the major vegetation, *Ficus carica* L., *Olea europaea* L. and *Vitis vinifera* L. can also be seen as very common plantation plants in those localities.

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MATERIAL AND METHODS

Four hundred and fifty moss specimens were collected from the study area during field trips arranged between 2009 and 2011. The relevant floras and monographs (Agnew & Vondráček 1975; Cano *et al*. 2005; Greven 1995; Heyn & Herrnstadt 2004; Hofmann 1998; Jimenez *et al*. 2005; Kürschner & Frey 2011; Muñoz 1999; Smith 2004; Zander 1993) were used for identifications of those specimens.

Moss and liverwort nomenclatures follow Hill *et al*. (2006) and Sabovljevic & Natcheva (2006). The recorded taxa were listed alphabetically. All specimens were deposited in the AYDN (Herbarium of Adnan Menderes University, Aydın, Turkey).

List of collection sites

1. Aaydın, City centre, Tralleis (22.01.2011) N37° 51' 38" E027° 50' 06" (144 m.)
2. Aydin, Sultanhisar, Nysa (25.01.2011) N37° 54' 12" E028° 08' 42" (230 m.)
3. Aydin, Çine, Alabanda (23.03.2011) N37° 35' 30" E027° 59' 06" (110 m.)
4. Aydin, Karacasu, Aphrodisias (01.04.2011) N37° 42' 32" E028° 43' 24" (520 m.)
5. Aydin, Söke, Magnesia (11.05.2011) N37° 51' 09" E027° 31' 38" (30 m.)
6. Aydin, Söke, Priene (11.05.2011) N37° 45'06" E027° 23' 49" (85 m.)
7. Aydin, Çine, Alinda (17.09.2011) N37° 33' 30" E027° 49' 43" (180 m.)
8. Muğla, Milas, Labranda (17.09.2011) N37° 22' 37" E027° 48' 03" (180 m.)
9. Aydin, Didim, Didyma (17.09.2011) N37° 23' 05" E027° 15' 22" (70 m.)
10. Aydin, Söke, Milethos (17.09.2011) N37° 47' 89" E027° 16' 40" (10 m.)

RESULTS AND DISCUSSION

A total of 129 moss taxa belonging to 18 families and 47 genera, 17 liverwort taxa belonging to 10 families and 13 genera were identified from ancient cities of the Aydin region. Among those taxa, *Ricciaceae* (4 taxa belonging to 1 genera) was the richest family in terms of species number within the hepatics. *Pottiaceae* (57 taxa belonging to 19 genera), *Orthotrichaceae* (14 taxa belonging to 2 genera), *Brachytheciaceae* (13 taxa belonging to 4 genera), *Bryaceae* (9 taxa belonging to 2 genera) and *Grimmiaceae* (8 taxa belonging to 2 genera) were the most species-rich families covering 77.9% of total moss flora within the mosses. *Lunularia cruciata, Funaria hygrometrica, Barbula unguiculata, B. convoluta, Timmiella barbuloides, Grimmia pulvinata, Ceratodon purpureus, Didymodon vinealis, D. luridus, D. acutus, Pseudocrossidium hornschuchianum, Bryum argenteum, B. caespiticium, B. capillare* and *B. dichotomum* were the most common species found and each was reported in more than five localities (Table 1). Apart from the liverwort *Lunularia cruciata*, the rest of those taxa mentioned above belong to acrocarpous mosses consisting of 83.2% (109 taxa) of the total flora. This would be an expected result due to climatic conditions of the research area.

Five taxa, *Fissidens fontanus, Crossidium aberrans*, *Didymodon bistratosus*, *Didymodon icmadophylus* and *Orthotrichum shawii* were collected from the study area as a second record in Turkey. *Fissidens fontanus* was firstly collected from the Amanos Mountains located in the southern part of Turkey (Dörtyol/Hatay) by Yayintaş & Allen (2009). This species spreads widely in man-made aquatic habitats across Europe (Sergio *et al*. 2010). We collected *F. fontanus* from submerged zones in water channels which are periodically dry during the summer period. Another species, *Didymodon icmadophylus,* was very recently collected from Middle East Anatolia (Karadağ/Konya) (Kirmaci *et al.* 2012). It closely resembles *D. acutus*, but differs in the long excurrent costa and the abaxial papillose upper laminal cells, which are quadrate to roundish-quadrate with weakly thickened cell walls (Kučera 2000). The second locality of *D. icmadophylus* is known to be far from the first collection localities. It is possible that it is more widespread in suitable habitats throughout Anatolia. Another interesting taxa was *Crossidium aberrans*, which was recently recorded as new by Ellis *et al.* (2012). It was collected from very dry habitats, close to the first locality. It can be easily distinguished from the other species of the genus by the leaf cells and ventral filaments (1-2 cell high, subglobose, densely papillose) (Baİ 2002). *Didymodon bistratosus* was first recorded from Turkey by Erdağ & Kürschner (2005), from only one locality in Asia until now. This species was collected from three localities in the present study. Also, the second report for Turkey of *Orthotrichum shawii* was made. It was recorded for the first time in the bryophyte flora of Turkey by Ellis *et al.* (2010). It morphologically resembles *O. striatum* and *O. rupestre*, but varies in sporophytic characters (see Mazimpaka *et al.* 2000 and Gariletti *et al*. 2006). These five species, except *Fissidens fontanus,* may be easily overlooked due to their minute size.

It is well-accepted that lichens and bryophytes, known as pioneer organisms, have an essential role in plant succession. Also, these pioneer organisms might damage historical places (Lisci *et al.* 2003; Stupar *et al.* 2013). In the research area, it was observed that two types of rock, marble and gneiss, had been typically used for

Table 1. List of bryophyte taxa
Abbreviations used throughout the text: S (on soil), R (on rock), SCR (on soil covering rock), E (epiphytic), D (on debris) and SW (on stone wall) and species marked with an asterisk (*) present the second records for Turkish bryophyte flora.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*SUBSTRT*
HEPATICS											
Corsinia coriandrina (Spreng.) Lindb.		*X*									*SCR*
Fossombronia echinata Macvicar						*X*					*S*
Fossombronia husnotii Corb.		*X*				*X*					*S*
Frullania dilatata (L.) Dumort.								*X*			*E*
Lunularia cruciata (L.) Dumort. ex Lindb.	*X*		*X*	*X*		*X*				*X*	*R-S-SCR*
Mannia fragrans (Balb.) Frye & L. Clark			*X*								*S*
Oxymitra incrassata (Brotero) Sérgio & Sim-Sim			*X*				*X*				*S*
Petalophyllum ralfsii (Wils.) Nees & Gottsche		*X*									*R*
Plagiochasma rupestre (Forst.) Steph.		*X*					*X*	*X*			*S*
Reboulia hemisphaerica (L.) Raddi			*X*			*X*		*X*			*S*
Riccia crozalsii Levier	*X*										*S*
Riccia glauca L.			*X*								*S*
Riccia lamellosa Raddi.		*X*				*X*					*S*
Riccia sorocarpa Bisch.	*X*	*X*				*X*					*S*
Southbya tophacea (Spruce) Spruce		*X*						*X*			*SW*
Sphaerocarpos texanus Austin		*X*	*X*								*S*
Targionia hypophylla L.			*X*			*X*					*S*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*SUBSTRT*
MOSSES											
Aloina aloides (Schultz) Kindb.						*X*					*S*
Aloina ambigua (Bruch & Schimp.) Limpr.	*X*	*X*									*S-SCR*
Anacolia webbii (Mont.) Schimp.							*X*	*X*			*S-SCR*
Anoectangium aestivum (Hedw.) Mitt.	*X*						*X*				*S*
Antitrichia californica Sull.							*X*				*E*
Antitrichia curtipendula (Hedw.) Brid.							*X*				*E*
Barbula convoluta var. *convoluta* Hedw.	*X*			*X*	*X*	*X*		*X*			*S-SCR*
Barbula convoluta var. *sardoa* Schimp.	*X*										*SW*
Barbula unguiculata Hedw.	*X*	*X*			*X*	*X*					*S-SCR*
Bartramia pomiformis Hedw.			*X*				*X*				*SCR*
Bartramia stricta Brid.			*X*				*X*				*R*
Bryum alpinum Huds. ex With.	*X*										*R*
Bryum argenteum Hedw.	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*M-R-SCR*
Bryum caespiticium Hedw.	*X*	*X*	*X*	*X*	*X*		*X*				*E-R-S-SW*
Bryum capillare Hedw.	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*S-SCR-SW*

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*SUBSTRT*
Bryum dichotomum Hedw.	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	***R-S-SCR-SW***
Bryum gemmilucens R. Wilczek & Demaret	*X*										***S***
Bryum moravicum Podp.			*X*								***E***
Bryum torquescens Bruch & Schimp.		*X*		*X*							***R-S-SW***
Ceratodon purpureus (Hedw.) Brid.	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	***R-S-SCR***
Cheilothela chloropus (Brid.) Broth.						*X*		*X*			***S***
**Crossidium aberrans* Holz. & E.B.Bartram			*X*								***SCR***
Crossidium squamiferum (Viv.) Jur.		*X*				*X*					***R-S-SCR-SW***
Dicranella heteromalla (Hedw.) Schimp.					*X*						***S***
Dicranella howei Renauld & Cardot		*X*								*X*	***S***
Dicranella varia (Hedw.) Schimp.		*X*			*X*						***S***
Didymodon acutus (Brid.) K. Saito		*X*	*X*	*X*	*X*	*X*					***R-S-SCR-SW***
Didymodon australasiae (Hook. & Grev.) R.H.Zander		*X*	*X*	*X*			*X*				***SCR-SW***
**Didymodon bistratosus* Hebrard & R.B.Pierrot								*X*			***SCR***
Didymodon cordatus Jur.						*X*					***R***
Didymodon fallax (Hedw.) R.H.Zander		*X*									***SCR***
**Didymodon icmadophylus* (Schimp. ex Müll.Hal) K. Saito				*X*							***D-SCR***
Didymodon insulanus (De Not.) M.O.Hill		*X*		*X*		*X*					***R-SCR-SW***
Didymodon luridus Hornsch. ex Spreng.	*X*	*X*	*X*	*X*		*X*	*X*				***E-R-S-SCR-SW***
Didymodon rigidulus Hedw.		*X*									***SCR***
Didymodon tophaceus (Brid.) Lisa		*X*			*X*	*X*					***R-S-SCR-SW***
Didymodon umbrosus (Müll.Hal) R.H.Zander		*X*									***SCR***
Didymodon vinealis (Brid) R. H. Zander	*X*	*X*	*X*	*X*	*X*	*X*		*X*			***S-SCR-SW***
Encalypta vulgaris Hedw.				*X*						*X*	***S***
Entosthodon convexus (Spruce) Brugués			*X*								***S-SCR***
Entosthodon pulchellus (H. Philib.) Brugués		*X*	*X*	*X*		*X*		*X*			***R-S-SW***
Epipterygium tozeri (Grev.) Lindb.							*X*				***S***
Fabronia pusilla Raddi			*X*				*X*	*X*			***E-SW***
Fissidens bryoides Hedw.				*X*		*X*					***S-SW***
Fissidens crispus Mont.						*X*					***S***
**Fissidens fontanus* (Bach.Pyl.) Lindb.								*X*			***R***
Fissidens viridulus var. *incurvus* (Starke ex Röhl.) Waldh.			*X*								***SW***
Fissidens viridulus var. *viridulus* (Sw.) Wahlenb.				*X*		*X*					***S-SCR-SW***
Funaria hygrometrica Hedw.	*X*	*X*	*X*	*X*	*X*						***R-S-SCR-SW***
Grimmia dissimulata E.Maier							*X*				***SW***
Grimmia hartmanii Schimp.							*X*				***R***
Grimmia laevigata (Brid.) Brid.		*X*	*X*	*X*			*X*				***R-SW***
Grimmia lisae De Not.		*X*	*X*				*X*				***R***
Grimmia ovalis (Hedw.) Lindb.			*X*	*X*				*X*			***R***

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*SUBSTRT*
Grimmia pulvinata (Hedw.) Sm.	X	X	X	X		X	X				E-M-R-SCR-SW
Grimmia trichophylla Grev.				X							R
Gymnostomum calcareum Nees & Hornsch.		X									R
Gymnostomum viridulum Brid.		X									R
Gyroweisia tenuis (Hedw.) Schimp.		X				X					R
Habrodon perpusillus (De Not.) Lindb.								X			E
Hedwigia ciliata var. *ciliata* (Hedw.) P.Beauv.							X	X			R-SW
Hedwigia ciliata var. *leucophaea* Bruch & Schimp.								X			R
Homalothecium lutescens (Hedw.) H.Rob.		X									SCR
Homalothecium sericeum (Hedw.) Schimp.		X	X	X			X	X			E-R-S-SCR-SW
Hygroamblystegium tenax (Hedw.) Jenn.								X			SW
Hymenostylium recurvirostrum (Hedw.) Dixon							X				SCR
Hypnum cupressiforme Hedw.		X				X	X				SCR
Isothecium myosuroides var. *brachythecioides* (Dixon) Braithw.			X			X					R-S
Leucodon sciuroides (Hedw.) Schwägr.		X						X			SCR
Microbryum davallianum (Sm.) R.H.Zander		X		X							S
Microbryum floerkeanum (F.Weber & D.Mohr) Schimp.	X										S
Microbryum starckeanum (Hedw.) R.H.Zander	X	X		X	X	X					S-SCR
Orthotrichum affine Schrad. ex Brid.								X			E
Orthotrichum anomalum Hedw.		X		X			X	X			R
Orthotrichum cupulatum var. *bistratosum* Schiffn.				X				X			M-SW
Orthotrichum cupulatum var. *cupulatum* Hoffm. ex Brid.		X		X							R-SW
Orthotrichum diaphanum Schrad. ex Brid.			X	X			X	X			E
Orthotrichum macrocephalum F. Lara, Garilleti & Mazimpaka								X			E
Orthotrichum pumilum Sw. ex anon.				X				X			E
Orthotrichum rupestre Schleich. ex Schwägr.							X	X			SW
**Orthotrichum shawii* Wilson							X				E
Orthotrichum speciosum Nees				X							E
Orthotrichum striatum Hedw.				X							E
Orthotrichum tenellum Bruch ex Brid.							X				R
Orthotrichum urnigerum Myrin				X							M
Oxyrrhynchium hians (Hedw.) Loeske							X				S
Oxyrrhynchium schleicheri (R.Hedw.) Röll		X									S
Oxyrrhynchium speciosum (Brid.) Warnst.		X									SCR
Phascum cuspidatum Schreb. ex Hedw.	X			X							S
Physcomitrium pyriforme (Hedw.) Bruch & Schimp.		X									S
Pleurochaete squarrosa (Brid.) Lindb.		X				X	X				S-SCR
Pseudocrossidium hornschuchianum (Schultz) R.H.Zander	X	X	X	X	X	X	X				R-S-SW

	1	2	3	4	5	6	7	8	9	10	SUBSTRT
Pseudocrossidium obtusulum (Lindb.) H.A.Crum & L.E.Anderson						X					R
Pseudocrossidium revolutum (Brid.) R.H.Zander			X			X					S-SW
Pterogonium gracile (Hedw.) Sm.		X	X			X	X	X			R-SCR-SW
Pterygoneurum ovatum (Hedw.) Dixon				X							S
Rhynchostegiella tenella (Dicks.) Limpr.				X							SW
Rhynchostegium confertum (Dicks.) Schimp.				X		X					S-SW
Rhynchostegium megapolitanum (F.Weber & D.Mohr) Schimp.				X							SW
Schistidium apocarpum (Hedw.) Bruch & Schimp.				X							SW
Sciuro-hypnum reflexum (Starke) Ignatov & Huttunen				X							D
Scleropodium cespitans (Müll.Hal.) L.F.Koch, Leafl.			X								SCR
Scleropodium touretii (Brid.) L. F. Koch			X								S
Scorpiurium circinatum (Bruch.) M. Fleisch. & Loeske			X			X					R-S-SCR-SW
Scorpiurium sendtneri (Schimp.) M. Fleisch.			X								R
Syntrichia echinata (Schiffn.) Herrnstadt & Ben-Sasson				X							E-M-SCR
Syntrichia laevipila Brid.							X				S
Syntrichia montana Nees		X		X							R-SW
Syntrichia papillosissima (Copp.) Loeske				X							S
Syntrichia princeps (De Not.) Mitt.				X				X			E-M-SW
Syntrichia ruralis (Hedw.) F.Weber & D.Mohr				X							SW
Syntrichia submontana (Broth.) Ochyra			X	X		X		X			E-M-R-SW
Syntrichia subpapillosissima (Bizot & R.B.Pierrot ex W.A.Kramer) M.T.Gallego & J. Guerra.				X							SW
Syntrichia virescens (De Not.) Ochyra				X							M
Timmiella anomala (Bruch & Schimp.) Limpr.				X							SW
Timmiella barbuloides (Brid.) Mönk.	X	X				X				X	R-S-SCR
Tortella humilis(Hedw.) Jenn	X										SCR-SW
Tortella tortuosa (Hedw.) Limpr.	X			X		X					R-SCR-SW
Tortula atrovirens (Sm.) Lindb.						X	X				SW
Tortula brevissima Schiffn.			X		X						R-SCR
Tortula cuneifolia (Dicks.) Turner	X						X				SCR-SW
Tortula inermis (Brid.) Mont.							X				SCR
Tortula lanceola R.H.Zander				X							SW
Tortula modica R.H.Zander			X								S
Tortula muralis Hedw.	X	X	X	X	X	X	X	X		X	E-R-S-SW-SCR
Tortula subulata Hedw.		X					X				SCR
Tortula truncata (Hedw.) Mitt.	X										S
Trichostomum crispulum Bruch					X					X	S
Weissia condensa var. *condensa* (Voit) Lindb.						X				X	R-SCR
Zygodon viridissimus (Dicks.) Brid.							X				E

constructing the ancient buildings in Aydın province. Our observation showed that gneiss (metamorphic rock) is more sensitive to degradation caused by bryophytes than marble (sedimentary rock) because of its physical structure and wavy surface. However, it was noticed that this effect has been solved by museum management only in Didyma ancient city by periodic disinfection of the buildings with very diluted liquid sodium hypochlorite to protect against all possible harmful organisms (personal communication). Because of the protection process, we found that Didyma ancient city is very poor in terms of bryophyte diversity compared with the others, as clearly demonstrated in Table 1. We found that *Grimmia pulvinata, Didymodon vinealis, Pseudocrossidium hornschuchianum, Tortula muralis, Bryum argenteum, B. capillare, B. dichotomum, Homalothecium sericeum* and *Pterogonium gracile* are the most common mosses living and spreading on gneiss rocks in our study area. Additionally, *Timmiella barbuloides,* which is another common moss, was frequently observed on recently excarated walls and between rocks used in ancient buildings. Thus, we suggest that this taxa can be used for vertical gardens, which are becoming popular in Europe and USA.

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Botanica SERBICA

REZIME

Flora briofita antičkih gradova u provinciji Ajdin (Turska)

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U radu se navode rezultati istraživanja briofita na području antičkih gradova u provinciji Ajdin u Turskoj. Medju 450 sakupljenih uzoraka konstatovano je 130 mahovinskih taksona (47 rodova rasporedjenih u 18 familija) i 16 jetrenjača (13 rodova rasporedjenih u 10 familija). Pet vrsta mahovina *Fissidens fontanus, Crossidium aberrans*, *Didymodon bistratosus*, *Didymodon icmadophylus* i *Orthotrichum shawii*, sa istraživanog područja navode se kao drugi nalaz za Tursku.

Ključne reči: Briofite, flora, antički gradovi, Ajdin, Turska.