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The Bryophyte Flora of the Vatican City State

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Abstract – For the first time, the bryological flora of the Vatican City State has been studied. Research concentrated in particular in the area of the Vatican Gardens, and led to the identification of 121 *taxa* of bryophytes (14 liverworts and 107 mosses), among which one liverwort and nine moss species are new reports for the Lazio Region. Particularly interesting among these species is the presence of *Tortula bolanderi* (Lesq. & James) M. Howe, the first report for the Italian peninsula. The study is of considerable floristic and biogeographical importance, and contributes significantly to the knowledge of a territory that until now had been unexplored from the bryological point of view.

Mosses / Liverworts / Vatican Gardens / *Tortula bolanderi* / Italian Peninsula

INTRODUCTION

The Vatican City State is an independent country, the smallest in the world in terms of population and size; its territory is an enclave within the Lazio Region of the Italian Republic.

Systematic bryological studies have not been conducted before in Vatican City. In fact, while numerous studies of the vascular and cryptogamic flora of the city of Rome have been carried out, they do not include this small country. The first to provide data on the bryological flora of the city of Rome were Fiorini Mazzanti (1877, 1878) and Brizi (1897-1898), who in the second half of the 1800s focused on some archaeological sites of the city. The one systematic study of the bryological flora of the city of Rome was conducted by Carcano (1989), who collected and reported 72 species of mosses in a portion of the urban area approximately corresponding to a transect from the center to the suburbs. The species collected were concentrated in the central archaeological zone and in areas occupied by public parks and villas.

The only information about bryophytes in Vatican City was provided by Bizot (1965) during a journey to Rome, when he collected from the base of a wall and on the terrace of the Dome of Saint Peter's Basilica 7 bryophytes (2 liverworts and 5 mosses). Thus the present study is the very first systematic contribution to knowledge about the bryological flora of Vatican City.

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STUDY AREA

The Vatican City State (41°54'01-27"N – 12°26'44"-27'30"E) covers an area of approximately 0.44 km^2 and is located on Vatican Hill (*ca* 100 m a.s.l.) within the urban area of the city of Rome.

Within the Vatican City the Vatican Gardens occupy about 23 hectares of the total of 44 hectares, extending from south to northwest in the small country. The remaining area is occupied by Saint Peter's Basilica and Square, the Apostolic Palace, the Vatican Museums, the Governorate Palace and other administrative buildings.

The first nucleus of the Vatican Gardens was established in 1279 when Pope Nicholas III had an orchard (*pomerium*), a lawn (*pratellum*) and a garden (*viridarium*) planted; in addition to the lawn and a fountain, it contained numerous forest trees. Expansions and modifications followed during the pontificates of Clement VII (1523-1534) and by his successor Paul III (1534-1549), who had the land levelled to create a new garden with covered avenues laid out in a cross pattern and enclosed by a high wall, for which it was called "*The secret garden*".

Since the end of the 1500s the structure of the Vatican Gardens has changed little. In the following centuries the only large-scale project was done by Paul V (1605 – 1621), who restored the ancient aqueduct of Trajan that brought water from the Bracciano Lake to Rome. This restored aqueduct, called the "*Acqua Paola*" (Water Paola) in the Pope's honor, made it possible to adorn the gardens with many fountains, among them the so-called "*Eagle*" fountain, named for the bird of prey that dominates the imposing cliff, and the spectacular "*Galley*" fountain, named for the great metal vessel that shoots jets and spurts of water from its canons (Barlo & Scaccioni, 2009; Campitelli, 2009).

The Vatican Gardens are composed of various zones named after the arrangement and provenance of the plant species present. In the Italian Garden (Fig. 1), established when the Vatican Gardens were first founded, the plants are arranged and pruned to obtain precise geometric forms. It is characterized prevalently by *Buxus sempervirens* L. hedges, and is surrounded by avenues of *Cedrus atlantica* Manetti, *Cupressus sempervirens* L., *Magnolia grandiflora* L., *Quercus ilex* L., and hedges of *Laurus nobilis* L.

The English Garden covers 2 hectares and is intentionally left natural, to give the illusion of being in open countryside (Fig. 2). It is characterized by numerous arboreal species, including *Acer monspessulanum* L., *Carpinus betulus L.*, *Quercus cerris* L., *Q. ilex* L., *Q. pubescens* Willd., *Q. rubra* L., and numerous typical undergrowth species. Inside the small wood there are streams, small waterfalls and numerous fountains, of which the most grandiose is that of the Eagle.

The American Garden features some very rare arboreal species, including an Australian silk-oak (*Grevillea robusta* A. Cunn.), and two very tall examples of dawn redwood (*Metasequoia glyptostroboides* Hu & Cheng.). It also hosts an avenue of *Olea europaea* L. and a wide variety of other trees from the American continent, including a majestic exemplar of *Acer negundo* L. that is 8 meters in diameter, *Ficus variegata* Blume and *Taxodium distichum* (L.) Rich.

The gardens are completed by numerous flowerbeds of exotic species from different parts of the world; of particular importance is the presence of some 15-meter-high exemplars of *Magnolia grandiflora* L., two exemplars of *Gingko biloba* L. and some 25-meter-high exemplars of *Araucaria bidwillii* Hook. There are numerous exemplars of *Cycas revoluta* Thunb., *Koerleuteria paniculata* Laxm and *Phoenix dactylifera* L. located throughout the gardens.

Fig. 1. The Italian Garden (Photographic Service of the Vatican Museums © Governorate of S.C.V. – Vatican Museums Management).

Fig. 2. The English Garden (Photographic Service of the Vatican Museums © Governorate of S.C.V. – Vatican Museums Management).

Fig. 3. The Eagle Fountain (detail) (Photographic Service of the Vatican Museums © Governorate of S.C.V. – Vatican Museums Management).

About 100 fountains embellish the gardens. In addition to the already mentioned Fountain of the Eagle, the most majestic and interesting from the bryological point of view (Fig. 3), and the Fountain of the Galley, others of note are the Fountain of the Shell, surrounded by hedges of *Buxus sempervirens* L. in a ray pattern, the Fountain of the Fish-Pond, next to the Academy of Sciences, the Fountain of the Cliff, which is built in an artificial cave of the Stein Garden, a rock garden two hundred metres long offering a variety of succulent xerophiles, and the Fountain of the Octagonal Court in the Vatican Museums. All these fountains are characterized by rich bryophytic cover and by vegetation of *Alocasia macrorrhizos* (L.) G. Don and *Cyperus papyrus* L.

According to the national ecoregional framework (Blasi *et al*., 2011), Vatican City is embedded within the Tyrrhenian Province of the Mediterranean Division and, more in detail, within the central-northern Tyrrhenian section, which is characterized by a key biogeographic location and a transitional climate. The occurrence in this section of a peculiar mixture of plant species with markedly different origins is due to the various phytogeographic influences from northern, southern, south-eastern and south-western Europe (Montelucci, 1978; Bolognini & Nimis, 1993; Capotorti *et al*., 2013). While the sub-Mediterranean climatic conditions, which fall between the strictly Mediterranean and Temperate ones, and are determined by a moderate drought in the summer period (Blasi *et al*., 1999; Blasi & Michetti, 2005), also influence the cryptogamic flora.

MATERIAL AND METHODS

The research was conducted between June 2013 and May 2014, in several phases. The first examined the entire area of Vatican City, while the later ones concentrated in the Vatican Gardens on areas with microclimatic and floristic characteristics of greater bryological interest, such as fountains, tree trunks, and flowerbed soil where there is persistent humidity.

The following list of bryophytes collected during this research gives each *taxon* in alphabetical order, with the location and environment where it was collected in Vatican City. When it was reported in the previous work of Bizot (1965) the location and habitat published is also given. Nomenclature follows Ros *et al.* (2007) for liverworts and Ros *et al.* (2013) for mosses. The samples are kept in the Herbarium of University of Camerino (CAME).

The new *taxa* for the Lazio Region (the geographic region within which Vatican City is located) are marked with asterisk (*).

RESULTS

The research conducted in the Vatican City State identified 121 bryophyte *taxa* (14 liverworts and 107 mosses). According to Aleffi *et al*. (2008), one liverwort and nine mosses are new records for the Lazio Region and one moss is new to the Italian peninsula.

List of taxa

Liverworts

Cephaloziella baumgartneri Schiffn. – Casina Pio IV: on shaded humid wall.

Cephaloziella divaricata (Sm.) Schiffn. – Casina Pio IV: on shaded humid wall. St. Peter Basilica: at the base of external wall (Bizot, 1965).

Chiloscyphus polyanthos (L.) Corda – Fountain of the Fish-Pond: on dripping stones.

****Conocephalum salebrosum*** Szweyk., Buczkowska & Odrzykoski – Fountain of the Fish-Pond and Fountain of the Cliff: on dripping stones.

Fossombronia caespitiformis De Not. *ex* Rabenh. var. ***caespitiformis*** – Fountain of the Shell: on shaded humid soil of flowerbeds.

Frullania dilatata (L.) Dumort. – English Garden: on bark of *Acer monspessulanum*, *Cycas revoluta*, *Koerleuteria paniculata, Quercus cerris*, *Q. ilex. A*merican Garden: on bark of *Cedrus atlantica*, *Olea europaea*, *Quercus ilex.*

Lunularia cruciata (L.) Lindb. – English Garden: on soil between the cobblestones.

Marchantia polymorpha subsp. ***ruderalis*** Bischl. & Boisselier – American Garden: on shaded humid soil of flowerbeds. St. Peter Basilica: at the base of external wall (Bizot, 1965).

Metzgeria furcata (L.) Dumort. – English Garden: on bark of *Populus canescens*, *Quercus cerris* and *Q. ilex.*

Pellia endiviifolia (Dicks.) Dumort. – English Garden: on dripping stones of the fountains. Fountain of the Fish-Pond and Fountain of the Cliff: on dripping stones.

Pellia epiphylla (L.) Corda – Fountain of the Eagle: on dripping stones.

Porella platyphylla (L.) Pfeiff. – English Garden: on bark of *Quercus cerris.*

Radula complanata (L.) Dumort. – English Garden: on bark of *Cycas revoluta*, *Populus canescens* and *Quercus cerris.* American Garden: on bark of *Cedrus atlantica.* Casina Pio IV: on bark of *Phoenix dactylifera.*

Sphaerocarpos michelii Bellardi – Fountain of the Shell: on shaded humid soil of flowerbeds.

Mosses

Amblystegium serpens (Hedw.) Schimp. – Fountain of the Shell: on shaded humid soil.

Anomodon viticulosus (Hedw.) Hook. & Taylor – Casina Pio IV: on humid soil of flowerbeds.

****Barbula bolleana*** (Müll. Hal.) Broth. – Fountain of the Eagle: on dripping stones

Barbula unguiculata Hedw. – English Garden: on bark of *Quercus cerris* and *Q. pubescens*; on volcanic stones of flowerbeds. Fountain of the Shell: on shaded humid soil of flowerbeds.

Brachythecium rivulare Schimp. – Fountain of the Fish-Pond and Fountain of the Eagle: on dripping stones.

Brachythecium rutabulum (Hedw.) Schimp. – English Garden: on volcanic stones of flowerbeds. Fountain of the Eagle: on dripping stones. Casina Pio IV: on bark of *Phoenix dactylifera*; on shaded stones.

Bryum argenteum Hedw. – Fountain of the Shell: on soil between the cobblestones.

Bryum dichotomum Hedw. – Casina Pio IV: on humid soil of flowerbeds.

Bryum gemmiparum De Not. – Fountain of the Eagle: on dripping stones.

Bryum radiculosum Brid. – Fountain of the Shell: on shaded volcanic stones.

Bryum ruderale Crundw. & Nyholm – Fountain of the Shell: on soil between the cobblestones.

Calliergonella cuspidata (Hedw.) Loeske – American Garden: on shaded humid soil of flowerbeds.

Ceratodon purpureus (Hedw.) Brid. – English Garden: on volcanic stones of flowerbeds. Fountain of the Cliff: on dripping stones.

Cinclidotus aquaticus (Hedw.) Bruch & Schimp. – Fountain of the Eagle: on dripping stones.

Cinclidotus fontinaloides (Hedw.) P. Beauv. – Fountain of the Fish-Pond: on dripping stones.

Ctenidium molluscum (Hedw.) Mitt. – Casina Pio IV: on humid soil of flowerbeds.

Dialytrichia mucronata (Brid.) Broth. – English Garden: on bark of *Quercus ilex.*

Dicranella varia (Hedw.) Schimp. – English Garden: on damp slope.

Didymodon fallax (Hedw.) R.H. Zander – Fountain of the Eagle, Fountain of the Galley and Fountain of the Cliff: on dripping stones.

Didymodon ferrugineus (Schimp. *ex* Besch.) M.O. Hill – Fountain of the Shell: on shaded volcanic stones.

Didymodon insulanus (De Not.) M.O. Hill – English Garden: on shaded stones of the flowerbeds. Fountain of the Shell: on dripping volcanic stones.

Didymodon luridus Hornsch. – English Garden: on volcanic stones of flowerbeds; on wet rocks of the fountains; on soil between the cobblestones. Fountain of the Shell: on shaded volcanic stones; on shaded humid soil of flowerbeds. Ethiopian College: on shaded soil of flowerbeds.

Didymodon sinuosus (Mitt.) Delogne – English Garden: on stone benches.

Didymodon spadiceus (Mitt.) Limpr. – Italian Garden: on shaded stones of the flowerbeds; on bark of *Cupressus sempervirens*.

Didymodon tophaceus (Brid.) Lisa – Fountain of the Fish-Pond, Fountain of the Cliff, Fountain of the Eagle, Fountain of the Octagonal Court: on dripping stones. Fountain of the Shell: on humid soil between the cobblestones. Casina Pio IV: on shaded humid stones.

Didymodon vinealis (Brid.) R.H. Zander – English Garden: on soil and volcanic stones of flowerbeds; on soil between the cobblestones. Fountain of the Cliff and Fountain of the Eagle: on dripping stones. Fountain of the Shell: on shaded volcanic stones; on shaded humid soil of flowerbeds. Ethiopian College: on shaded soil of flowerbeds.

Drepanocladus aduncus (Hedw.) Warnst. – Fountain of the Eagle: on dripping stones.

Eucladium verticillatum (With.) Bruch & Schimp. – English Garden: on dripping stones of the fountains. Fountain of the Eagle and Fountain of the Octagonal Court: on dripping stones.

Eurhynchiastrum pulchellum (Hedw.) Ignatov & Huttunen var. ***pulchellum*** – Ethiopian College: on shaded soil of flowerbeds. Casina Pio IV: on bark of *Phoenix dactylifera.*

Fabronia pusilla Raddi – English Garden: on bark of *Cycas revoluta*, *Quercus cerris* and *Q. ilex.* American Garden: on bark of *Olea europaea.* Ethiopian College: on bark of *Magnolia grandiflora.* Casina Pio IV: on bark of *Taxus baccata.*

Fissidens crassipes Wilson *ex* Bruch & Schimp. subsp. ***crassipes*** – Fountain of the Fish-Pond and Fountain of the Eagle: on dripping stones.

****Fissidens crispus*** Mont. – English Garden: on humid soil of flowerbeds. Fountain of the Galley: on dripping stones. Fountain of the Shell: on shaded humid soil. American Garden: on shaded humid soil of flowerbeds.

Fissidens pusillus (Wilson) Milde – Fountain of the Shell: on shaded humid soil of flowerbeds.

Fissidens serrulatus Brid. – English Garden: on damp slope.

Fissidens viridulus (Sw. ex anon.) Wahlenb. var. ***viridulus*** – English Garden: on volcanic stones of flowerbeds. St. Peter Basilica: at the base of external wall (Bizot, 1965).

Fissidens viridulus var. ***incurvus*** (Starke ex Röhl.) Waldh. – Fountain of the Cliff: on dripping stones. Fountain of the Shell: on shady humid soil.

Funaria hygrometrica Hedw. – Fountain of the Shell: on soil between the cobblestones.

****Grimmia lisae*** De Not. – English Garden: on shaded stones of the flowerbeds. American Garden: on granitic boulders.

Grimmia pulvinata (Hedw.) Sm. – Casina Pio IV: on shaded humid wall.

Grimmia trichophylla Grev. – English Garden: on stone benches; on shaded stones of the flowerbeds. American Garden: on granitic boulders. Fountain of the Shell: on shaded volcanic stones. Ethiopian College: on shaded soil of flowerbeds.

Gymnostomum calcareum Nees & Hornsch. – Fountain of the Fish-Pond: on dripping stones. Casina Pio IV: on shaded humid wall.

****Gymnostomum viridulum*** Brid. – Casina Pio IV: on shaded humid wall.

Gyroweisia tenuis (Hedw.) Schimp. – Fountain of the Galley: on dripping stones.

Habrodon perpusillus (De Not.) Lindb. – English Garden: on bark of *Koerleuteria paniculata.*

****Hedwigia stellata*** Hedenäs – English Garden: on bark of *Koerleuteria paniculata.*

Homalothecium lutescens (Hedw.) H. Rob. var. ***lutescens*** – Casina Pio IV: on humid soil of flowerbeds.

Homalothecium sericeum (Hedw.) Schimp. – English Garden: on bark of *Acer monspessulanum*, *Populus canescens*, *Quercus cerris*, *Q. ilex* and *Q. pubescens*; on wet rocks of the fountains.

****Hygroamblystegium fluviatile*** (Hedw.) Loeske – Fountain of the Cliff and Fountain of the Eagle: on dripping stones.

Hygroamblystegium tenax (Hedw.) Jenn. – Fountain of the Cliff and Fountain of the Eagle: on dripping stones.

Hypnum cupressiforme Hedw. var. ***cupressiforme*** – English Garden: on soil and stones of flowerbed; on stone benches; on bark of *Acer monspessulanum*, *Koerleuteria paniculata*, *Populus canescens*, *Quercus cerris* and *Q. pubescens*; on wet rocks of the fountains; on soil between the cobblestones. American Garden: on bark of *Cedrus atlantica*, *Libocedrus decurrens*, *Olea europaea* and *Quercus ilex.* Ethiopian College: on bark of *Magnolia grandiflora.* Casina Pio IV: on bark of *Phoenix dactylifera.*

Hypnum cupressiforme var. ***filiforme*** Brid. – English Garden: on bark of *Quercus cerris.*

Isothecium alopecuroides (Lam. *ex* Dubois) Isov. – Casina Pio IV: on humid soil of flowerbeds.

Kindbergia praelonga (Hedw.) Ochyra – Fountain of the Cliff and Fountain of the Eagle: on dripping stones.

Leptodon smithii (Hedw.) F. Weber & D. Mohr – English Garden: on bark of *Populus canescens*, *Quercus cerris*, *Q. ilex* and *Q. pubescens*; on wet rocks of the fountains and flowerbeds. American Garden: on bark of *Libocedrus decurrens.*

Leptodyctium riparium (Hedw.) Warsnt. – Fountain of the Eagle and Fountain of the Octagonal Court: on dripping stones.

Leucodon sciuroides (Hedw.) Schwägr. – English Garden: on bark of *Quercus cerris.*

Microeurhynchium pumilum (Wilson) Ignatov & Vanderp. – Fountain of the Eagle: on dripping stones. Ethiopian College: on shaded soil of flowerbeds.

Nogopterium gracile (Hedw.) Crosby & W.R. Buck – English Garden: on bark of *Quercus ilex.*

****Orthotrichum acuminatum*** H. Philib. – English Garden: on bark of *Koerleuteria paniculata.*

Orthotrichum affine Schrad. *ex* Brid. – American Garden: on bark of *Olea europaea* and *Taxodium distichum.*

Orthotrichum diaphanum Schrad. *ex* Brid. – English Garden: on bark of *Acer monspessulanum*, *Cycas revoluta*, *Populus canescens*, *Quercus cerris, Q. ilex* and *Q. pubescens*; on shaded stones of the flowerbeds. American Garden: on bark of *Cedrus atlantica*, *Ficus variegata*, *Quercus ilex* and *Taxodium distichum.*

Orthotrichum lyellii Hook. & Taylor – English Garden: on bark of *Quercus cerris.*

Orthotrichum speciosum Nees – English Garden: on bark of *Quercus cerris.*

Orthotrichum stramineum Hornsch. *ex* Brid. – English Garden: on bark of *Quercus pubescens.*

Orthotrichum tenellum Bruch *ex* Brid. – English Garden: on bark of *Koerleuteria paniculata.*

Oxyrrhynchium hians (Hedw.) Loeske – English Garden: on soil of the flowerbeds.

Oxyrrhynchium speciosum (Brid.) Warnst. – English Garden: on stones of the fountains. Fountain of the Eagle: on dripping stones.

Philonotis calcarea (Bruch & Schimp.) Schimp. – Fountain of the Eagle: on dripping stones.

Philonotis fontana (Hedw.) Brid. – Fountain of the Eagle: on dripping stones.

Philonotis marchica (Hedw.) Brid. – Fountain of the Eagle: on dripping stones.

****Philonotis rigida*** Brid. – Fountain of the Eagle: on dripping stones.

Plagiomnium elatum (Bruch & Schimp.) T.J. Kop. – English Garden: on damp slope. Fountain of the Shell: on shaded humid soil of flowerbeds. American Garden: on shaded humid soil of flowerbeds.

Plagiomnium medium (Bruch & Schimp.) T.J. Kop. – Fountain of the Shell: on shaded humid soil of flowerbeds.

Plagiomnium undulatum (Hedw.) T.J. Kop. – Ethiopian College: on shaded soil of flowerbeds.

Plagiomnium rostratum (Schrad.) T.J. Kop. – Ethiopian College: on shaded soil.

Pohlia melanodon (Brid.) A.J. Shaw – Fountain of the Eagle: on dripping stones.

Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews var. ***wahlenbergii*** – Fountain of the Eagle: on dripping stones.

Pseudoleskeella catenulata (Brid. *ex* Schrad.) Kindb. – English Garden: on bark of *Quercus cerris.* Casina Pio IV: on bark of *Phoenix dactylifera.*

Pseudoleskeella nervosa (Brid.) Nyholm – English Garden: on stone benches, on bark of *Quercus cerris* and *Q. pubescens*; on wet rocks of the fountains.

Pseudoscleropodium purum (Hedw.) M. Fleisch. – American Garden: on shaded humid soil of flowerbeds.

Ptychostomum capillare (Hedw.) D.T. Holyoak & N. Pedersen – English Garden: on bark of *Cycas revoluta*, *Koerleuteria paniculata*, *Populus canescens*, *Quercus cerris* and *Q. pubescens*; on volcanic stones of the flowerbeds; on wet rocks of the fountains; on soil between the cobblestones. American Garden: on bark of *Olea europaea* and *Taxodium distichum.* Casina Pio IV: on bark of *Phoenix dactylifera.*

Ptychostomum donianum (Grev.) D.T. Holyoak & N. Pedersen – Casina Pio IV: on shaded humid wall.

Ptychostomum imbricatulum (Müll. Hal.) D.T. Holyoak & N. Pedersen – English Garden: on volcanic stones of flowerbeds. Fountain of the Galley: on dripping stones. Fountain of the Shell: on shaded volcanic stones.

Ptychostomum pallens (Sw.) J.R. Spence – Fountain of the Galley: on dripping stones.

Ptychostomum pseudotriquetrum (Hedw.) J.R. Spence & H.P. Ramsay – Casina Pio IV: on shaded humid wall.

Ptychostomum torquescens (Bruch & Schimp.) Ros & Mazimpaka – Fountain of the Shell: on shaded humid soil of flowerbeds.

Rhynchostegiella curviseta (Brid.) Lindb. – English Garden: on bark of *Populus canescens.* Casina Pio IV: on shaded humid wall. St. Peter Basilica: at the base of external wall (Bizot, 1965).

Rhynchostegiella tenella (Dicks.) Limpr. – English Garden: on humid soil; on wet rocks of the fountains; on bark of *Cycas revoluta* and *Quercus ilex*; on volcanic stones of flowerbeds. Fountain of the Galley: on dripping stones. American Garden: on bark of *Cedrus atlantica.* Ethiopian College: on shaded soil of flowerbeds. Fountain of the Shell: on shaded humid soil of flowerbeds. Casina Pio IV: on bark of *Phoenix dactylifera.* St. Peter Basilica: at the base of external wall (Bizot, 1965).

Rhynchostegium confertum (Dicks.) Schimp. – English Garden: on wet rocks of the fountains; on soil of the flowerbeds.

Rhynchostegium megapolitanum (Blandow *ex* F. Weber & D. Mohr) Schimp. – English Garden: on soil of the flowerbeds. Fountain of the Eagle: on dripping stones. Ethiopian College: on shaded soil of flowerbeds.

Rhynchostegium riparioides (Hedw.) Cardot – Fountain of the Fish-Pond and Fountain of the Eagle: on dripping stones.

Sciuro-hypnum plumosum (Hedw.) Ignatov & Huttunen – Casina Pio IV: on bark of *Phoenix dactylifera.*

Scorpiurium circinatum (Bruch) M. Fleisch & Loeske – English Garden: on soil between the cobblestones; on soil and volcanic stones of the flowerbed; on bark of *Populus canescens*, *Quercus cerris* and *Q. ilex*. Fountain of the Cliff: on dripping stones. American Garden: on bark of *Cedrus atlantica* and *Olea europaea.* Fountain of the Shell: on shaded humid soil and shaded volcanic stones. Italian Garden: on bark of *Cupressus sempervirens*; on shaded humid soil. Ethiopian College: on shaded soil. Casina Pio IV: on bark of *Phoenix dactylifera.* St. Peter Basilica: at the base of external wall (Bizot, 1965).

Syntrichia laevipila Brid. – English Garden: on stone benches; on bark of *Acer monspessulanum*, *Koerleuteria paniculata*, *Populus canescens*, *Quercus cerris* and

Q. pubescens. American Garden: on bark of *Quercus ilex* and *Taxodium distichum.* Fountain of the Shell: on shaded volcanic stones. Italian Garden: on bark of *Cupressus sempervirens.* Ethiopian College: on shaded soil of flowerbeds; on bark of *Magnolia grandiflora.* Casina Pio IV: on bark of *Phoenix dactylifera*; on shaded stones.

Syntrichia papillosa (Wilson) Jur. – English Garden: on bark of *Koerleuteria paniculata* and *Quercus ilex.* American Garden: on bark of *Cedrus atlantica*, *Libocedrus decurrens*, *Olea europaea* and *Taxodium distichum.* Italian Garden: on bark of *Cupressus sempervirens.* Ethiopian College: on bark of *Magnolia grandiflora.*

Syntrichia ruralis (Hedw.) F. Weber & D. Mohr var. ***ruralis*** – Casina Pio IV: on shaded stones; on shaded humid wall.

Tortella inflexa (Bruch) Broth. – English Garden: on volcanic stones of flowerbeds.

Tortella nitida (Lindb.) Broth. – English Garden: on fountains stones. Fountain of the Shell: on shaded volcanic stones. Ethiopian College: on shaded soil of flowerbeds. Casina Pio IV: on shaded stones; on humid soil of flowerbeds.

****Tortula bolanderi*** (Lesq. & James) M. Howe – Fountain of the Shell: on shaded volcanic stones.

Tortula canescens Mont. – English Garden: on rocks of the fountains.

Tortula marginata (Bruch & Schimp.) Spruce – Fountain of the Cliff: on dripping stones.

Tortula muralis Hedw. – English Garden: on shaded stones of the flowerbeds. Fountain of the Galley: on stones. St. Peter Basilica: at the base of external wall (Bizot, 1965).

Tortula subulata Hedw. – Fountain of the Shell: on shaded humid soil of flowerbeds.

Trichostomum brachydontium Bruch – English Garden: on soil between the cobblestones.

Trichostomum crispulum Bruch – English Garden: on volcanic stones of flowerbeds. Fountain of the Shell: on soil between the cobblestones.

Weissia condensa (Voit) Lindb. – Casina Pio IV: on shaded stones.

Zygodon rupestris Schimp. *ex* Lorentz – English Garden: on stone benches, on bark of *Acer monspessulanum*, *Populus canescens*, *Quercus cerris*, *Q.ilex* and *Q. pubescens*; on wet rocks of the fountains. American Garden: on bark of *Libocedrus decurrens*, *Olea europaea*, *Quercus ilex* and *Taxodium distichum.* Casina Pio IV: on bark of *Phoenix dactylifera.*

DISCUSSION

Among the collected species particularly interesting are the finding of *Tortula bolanderi*, an oceanic-Mediterranean species to date reported only for Sicily (on the vertical walls along the Vizzini-Caltagirone road) by Blockeel (1995), it is to be considered the first report for the Italian peninsula. It is known from N. America (Zander & Eckel, 2007), Northern Africa (Morocco) and in a few localities in Europe: the Canary Islands, Madeira, France, Portugal and Spain (Ros *et al.*, 2013).

Another interesting finding is *Conocephalum salebrosum*. This species was reported in Italy by Tacchi *et al.* (2009) at Infernaccio gorges in the Marche Region, by Privitera *et al.* (2010) in the Carnic Alps (Friuli-Venezia Giulia Region), and recently in the Marmore Waterfalls (Umbria Region) by Poponessi *et al.* (2014). It is a Holarctic species, with known locations in Europe, East Asia and North America (Szweykowski *et al.*, 2005).

Barbula bolleana is a very rare species in Italy, recorded only for Trentino-Alto Adige (Pokorny *et al.*, 2006), Lombardy (Giacomini, 1950), Tuscany (Renauld, 1880), Sardinia (Cortini Pedrotti & Troiano, 1985) and Sicily (Brullo *et al*., 1989; Dia *et al.*, 2003). This species is widespread in Mediterranean basin: Algerie, Balearic Islands, Crete, Croatia, Cyprus, Egypt, France, Greece, Iberian peninsula, Israel, Jordan, Lebanon, Libya, Malta, Morocco, Portugal, Syria, Tunisia and Turkey (Ros *et al*., 2013). It occurs also in Sub Saharan Africa (O'Shea, 2006) and North America (Zander, 2007).

Orthotrichum acuminatum in Italy is only known in Trentino-Alto Adige (Philibert, 1881) and Tuscany (Levier, 1905) until it was reported from Calabria (Lara *et al.,* 2004), Campania (Preston & Blockeel, 2006), Sardinia (Blockeel *et al.*, 2009) and Sicily (Lo Giudice *et al.*, 2000). It is a circummediterranean species, moderately xerophilous and thermophilous, which has its main known distribution in the Balearic Islands and Canary islands, Corsica, Iberian peninsula, Madeira, Portugal, and Southern France (Philibert, 1881; Lara & Mazimpaka, 1992; Casas, 1994; Lara *et al.*, 1999). It occurs also in Algeria, Bosnia-Herzegovina, Bulgaria, Crete, Croatia, Cyprus, Greece, Montenegro, Morocco, Tunisia and Turkey (Ros *et al.,* 2013).

Finally, the record of *Didymodon spadiceus* is a surprising presence because is usually a plant distributed on mountain areas of southern Europe (Ros *et al.,* 2013) and in the Alpine and the Apennines regions of Italy (Cortini Pedrotti *et al*., 1991; Codogno & Di Montegnacco, 1995; Aleffi *et al*., 1997; Schumacker & Soldán, 1997; Perego & Sguazzin, 2005; Sguazzin & Perego, 2011), including Sicily (Aiello & Dia, 2004) and Sardinia (Aleffi *et al*., 1995; Cogoni *et al*., 2002). In addition to Europe, the species is also present in Asia (Jiménez *et al*., 2005). The specimen has sporophytes and appears to be typical.

The presence of all these species is strictly related to the particular ecological and microclimatic conditions in the Vatican Gardens, due to habitats diversity and to the permanent conditions of humidity present in the entire area but in particular on the fountain stones and in the soil of the flowerbeds, which receive constant artificial irrigation.

This greater biodiversity is even more evident if you compare with similar studies conducted in some gardens of the city of Rome and other cities of southern Italy and Spain. In fact, in the study of the bryological flora of the city of Rome conducted by Carcano (1989) in a portion of the urban area, who reported 72 species of mosses, in the gardens of the main urban villas of the city, including Villa Borghese, Villa Doria Pamphilj and Villa Torlonia, were found on average between 20 and 30 bryophyte taxa. In a similar study conducted by Dia *et al.* (2003) in some cities of Sicily, floristic diversity is much lower than that found in the Vatican Gardens. In fact, with the exception of the city of Enna (103 taxa) and the city of Agrigento (55 taxa), the number of bryophytes reported overall in the gardens and parks of the city of Catania, Palermo and Siracusa is around 80 taxa. Much lower the number of taxa (between 30 and 60) reported from Soria & Ron (1995) in some Spanish cities.

This study of the bryological flora of the Vatican City State contributes significantly not only to the knowledge of a territory which until now had been

unexplored from the bryological point of view, but also provides important floristic and chorological information for the realization and definition of the European Red List of Mosses, currently being conducted. According to the *Red data book of European bryophytes* (ECCB, 1995), *Tortula bolanderi* is considered as Vulnerable in Europe, even if this little-know species needs further investigation to determine its status in more detail and any threats to it. Other species considered rare in Italy according to Aleffi *et al*. (2008), are *Barbula bolleana*, *Hedwigia stellata*, *Hygroamblystegium fluviatile* and *Orthotrichum acuminatum*.

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