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Contribution to the knowledge of the Bryophyte Flora of the Vatican City State: The Pontifical Villas of Castel Gandolfo (Rome, Italy)

Abstract

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For the first time, the bryoflora of the Pontifical Villas of Castel Gandolfo (Vatican City State) has been studied. Research led to the identification of 87 bryophytes (1 hornworts, 15 liverworts and 71 mosses), among which one liverwort and six moss species are new reports for the Lazio Region. *Zygodon forsteri*, epiphyte species considered Vulnerable in Europe, *Anthoceros agrestis* and other species rare for Italy, were found in the study area. In addition, the life-form of each species was taken into consideration, in order to compare with the ecological and climatic characteristics of the territory examined. The study contributes to the knowledge of a territory of the Vatican City State that until now had been almost unexplored from the bryological point of view and provides important information for the realization and definition of the European and Mediterranean Red List of Bryophytes.

Key words: Bryophytes, *Anthoceros agrestis*, *Zygodon forsteri*, Life-forms, Lazio Region.

Introduction

This work, conducted in the Pontifical Villas of Castel Gandolfo, completes the research carried out on the bryological flora of the Vatican Gardens (Aleffi 2015), providing more detailed information for the production of the Check-List and country status of European Bryophytes.

Previously, numerous studies of the vascular and cryptogamic flora of the city of Rome have been carried out but they did not include this small country. The information about bryophytes in Vatican City was provided only by Bizot (1965) who collected some species from the Dome of Saint Peter's Basilica, and recently by Aleffi (2015), who identified 121 *taxa* mostly concentrated in the Vatican Gardens.

Study area

The Pontifical Villas of Castel Gandolfo comprise about 55 hectares: 30 ha make up a garden, while 25 ha are used for farming. The latter is carried out with full regard for the

aesthetics proper to countryside gardening. The Pontifical Villas complex includes the Papal Palace, the Barberini Palace and Villa Cybo, and extends from the top of the hill of Castel Gandolfo (41°44'48.65" N – 12°38'56.79" E), where the Papal Palace is located, as far as the residential area of Albano (41°43'53.21" N – 12°39'30.34" E), along the south-western edge of the crater that forms Lake Albano, in a dominating position facing the Tyrrhenian Sea, at an altitude between 400 m and 450 m a.s.l.

The Pontifical Villas were built on the ruins of the central part of the summer residence of the Emperor Domitian (81-96 AD), which covered about 14 km^2 from the Appian Way to the shores of Lake Albano. After the death of Domitian, the imperial villa quickly began to deteriorate. It was only in July 1596, under the pontificate of Clement VIII, that the Apostolic Chamber took possession of the villas. Pope Clement XIV further enlarged the palace in March 1773 by acquiring the adjacent Villa Cybo. The Pontifical Villas took on their current dimensions after the Lateran Pacts of 1929, with the acquisition of the Villa Barberini complex, where gardens of a new design were established. Worthy of particular mention among these gardens is the Belvedere Garden. Pius XI completed the residence with the acquisition of some gardens toward Albano to create a farm (Fig. 1).

The area of the Pontifical Villas is part of the Roman Castles, an area of volcanic nature that originated with the collapse of the Latium Volcano several hundreds of thousands of years ago. The main opening of the Latium Volcano occupied the entire area of the inner belt of the Castles: its subsequent collapse gave rise to various secondary openings, the most important of which is the current Mont Cavo (949 m a.s.l.). The other minor openings of the Volcano became

Fig. 1. The extensive area of farmland planted with olive trees is characterized by an interesting bryoflora.

lacustrine basins during the hydromagmatic phase of the Latium Volcano through the encounter between magma and subsoil water between 100,000 and 20,000 years ago, the most important of which are Lake Albano and Lake Nemi; most of the other basins have been drained over the course of the centuries (Funiciello & Parotto 1978; Giordano & al. 2006).

According to the classification data of the National Geological Service (1961), most of the territory of the Roman Castles is composed of material from the final eruptions, which gave rise to the famous *peperino*, a material widely used in the construction of many buildings, including all of the Pontifical Villas.

From the climatic point of view, according to the classification of the ecoregions of Italy (Blasi & al. 2014), the studied area is part of the Mediterranean Division (Northern and Central Tyrrhenian Section of the Tyrrhenian Province) with mild winters, autumn temperatures higher than the spring ones, and breezy summers. Average annual precipitation is around 900-1000 mm with a reduction from January-February to July-August and a sharp increase in September.

The Alban Hills are marked by a phenomenon called the *stau*: the water vapor diminishes as the land elevation increases. Thus the greatest rainfall occurs on the first highlands of the Alban Hills, facing the Sea. Normally the area is subject to winds from the southwest, namely the *scirocco* and *libeccio*. Instead, during the winter there are the strong cool winds from the north and northeast, the *tramontana* and *grecale* winds.

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 & al. 1999; Blasi & Michetti 2005), influence the cryptogamic flora.

Material and Methods

The research was conducted between September 2014 and May 2015 in several phases. The first examined the entire area of the Pontifical Villas, while the later ones concentrated on areas with microclimatic and floristic characteristics of greater bryological interest, such as tree trunks (Fig. 2), archaeological sites and flowerbed soils where there is persistent humidity, with particular regard to the following sites:

the Avenue of Holm Oaks which is adjacent to the entrance of Villa Barberini and reaches the square bordered by the Roman Amphitheatre; an analogous avenue, formed of centuries-old holm oaks, is located between the olive grove of the farm and the Belvedere gardens; *Domitians's Amphitheatre*: built on the pre-existing structures of the Villa of Domitian (81-96 A.D.), characterized by a series of steps originally covered with polychrome marble, and by a theatre building in packed earth;

the Avenue of the Nympheums: starting from the Amphitheatre, currently form the backdrop for the centuries-old trees that compose the Italian-style garden;

Belvedere Gardens: divided into three parterres, the historic gardens are the heart of Villa Barberini, and extend beyond the 300 meters of length of the cryptoporticus that runs alongside them; the gardens are bordered by an avenue of aromatic herbs where numerous officinal plants are cultivated (Fig. 3).

The following list of bryophytes collected during this research gives each *taxon* in alphabetical order, with the location and environment where it was collected. Nomenclature follows Ros & al. (2007) for liverworts and Ros & al. (2013) for mosses. The chorotypes and

Fig. 2. The holm oaks gallery presents special moisture conditions that favor the growth of bryophytes on tree trunks and rocks.

Fig. 3. The Belvedere Gardens is the traditional Italian garden: the first level reproduces the design of a coffered ceiling.

the ecological features are drawn from Dierβen (2001); the life forms from Hill & al. (2007). The samples are kept in the Herbarium of University of Camerino (CAME).

The new *taxa* for the Lazio Region (the geographic region within which the Castel Gandolfo Villas are located) are marked with asterisk (*).

Results

The research conducted in the Pontifical Villas of Castel Gandolfo identified 87 bryophytes: 1 hornwort, 15 liverworts and 71 mosses (Table 1). Of these, 1 hornwort, 4 liverworts and 23 mosses are additions to the bryoflora of the Vatican City State (Aleffi 2015). According to Aleffi & al. (2008), one liverwort and seven mosses are new records for the Lazio Region.

List of *taxa*

Hornworts and Liverworts

**Anthoceros agrestis* Paton: on shaded humid soil of the Roman Amphitheatre.

Cephaloziella baumgartneri Schiffn.: on shaded humid stones of *Opus reticulatum*.

Cololejeunea rossettiana (C. Massal.) Schiffn.: on bark of *Quercus ilex.*

Conocephalum salebrosum Szweyk., Buczkowska & Odrzykoski: on shaded humid stones of *Opus reticulatum*.

Fossombronia angulosa (Dicks.) Raddi: on shaded humid soil of the Roman Amphitheatre.

Fossombronia caespitiformis Rabenh.: on shaded humid soil of the Roman Amphitheatre.

Frullania dilatata (L.) Dumort.: on bark of *Arbutus unedo*, *Cedrus atlantica*, *Quercus ilex*.

Lejeunea cavifolia (Ehrh.) Lindb.: on bark of *Quercus ilex*; on stones of *Nymphaeum* and Roman Amphitheatre.

Lunularia cruciata (L.) Lindb.: on soil of flowerbeds, *Nymphaeum* and Roman Amphitheatre; on stones of *Opus reticulatum*.

Marchantia polymorpha subsp. *ruderalis* Bischl. & Boisselier: on humid soil of the *Nymphaeum* and flowerbeds.

Metzgeria furcata (L.) Dumort.: on bark of *Arbutus unedo*, *Cedrus atlantica*, *Cupressus sempervirens*, *Quercus ilex*; on shaded stones of the *Nymphaeum*.

Pellia endiviifolia (Dicks.) Dumort.: on shaded humid stones of *Opus reticulatum.*

Porella platyphylla (L.) Pfeiff.: on bark of *Olea europaea* and *Quercus ilex*.

Radula complanata (L.) Dumort.: on bark of *Quercus ilex*.

Sphaerocarpos michelii Bellardi: on shaded humid soil of the Roman Amphitheatre.

Targionia hypophylla L.: on shaded stones of *Opus reticulatum*; on damp slope.

Mosses

Alleniella besseri (Lobarz.) S. Olsson, Enroth & D. Quandt: on shaded stones of the *Nymphaeum*.

Alleniella complanata (Hedw.) S. Olsson, Enroth & D. Quandt: on bark of *Quercus ilex*.

Aloina rigida (Hedw.) Limpr.: on soil of the Roman Amphitheatre.

Amblystegium serpens (Hedw.) Schimp.: on shaded stones of *Opus reticulatum*.

Barbula convoluta Hedw.: on shaded humid soil of the Roman Amphitheatre and on flowerbeds.

Barbula unguiculata Hedw.: on soil of flowerbeds.
Brachythecium rutabulum (Hedw.) Schimp.: on soil of flowerbeds.
Brachythecium salebrosum (F. Weber & D. Mohr) Schimp.: on soil of flowerbeds.
Bryum argenteum Hedw.: on soil of the vineyard.
**Bryum elegans* Nees: on humid soil of the Roman Amphitheatre.
Ceratodon purpureus (Hedw.) Brid.: on soil of flowerbeds; on stone benches.
**Cynodontium bruntonii* (Sm.) Bruch & Schimp.: on shaded volcanic stones.
Dicranella howei Renauld & Cardot: on soil of the Roman Amphitheatre.
Didymodon insulanus (De Not.) M. O. Hill: on stone benches.
Didymodon luridus Hornsch.: on stone benches; on soil and stones of the Roman Amphitheatre and *Nymphaeum.*
Didymodon rigidulus Hedw.: on stones of the Roman Amphitheatre.
Didymodon sinuosus (Mitt.) Delogne: on stone benches; on stones of *Nymphaeum*; on stones of the path of live oaks.
Didymodon vinealis (Brid.) R. H. Zander: on soil and stones of the Roman Amphitheatre; on stones of flowerbeds; on stones of the path of live oaks.
Enthostodon convexus (Spruce) Brugués: on stones of the Roman Amphitheatre.
Eucladium verticillatum (With.) Bruch & Schimp.: on stones of the Roman Amphitheatre; on shaded stones of *Opus reticulatum*.
Eurhynchiastrum pulchellum (Hedw.) Ignatov & Huttunen var. *pulchellum*: on stone benches; on stones of the path of live oaks.
Eurhynchium striatum (Hedw.) Schimp.: on shaded stones of *Opus reticulatum.*
Fabronia pusilla Raddi: on bark of *Cupressus sempervirens* and *Quercus ilex.*
Fissidens crispus Mont.: on stones of the Roman Amphitheatre; humid soil of the path of live oaks.
Fissidens exilis Hedw.: on stones of the *Nymphaeum*; on stones of the path of live oaks.
Fissidens ovatifolius R. Ruthe: on damp slope.
Fissidens viridulus var. *incurvus* (Röhl.) Waldh.: on shaded stones of *Opus reticulatum*; on soil of flowerbeds.
Fissidens viridulus (Sw.) Wahlenb. var. *viridulus*: on humid soil of the path of live oaks.
Funaria hygrometrica Hedw.: on soil of flowerbeds and the vineyard.
Grimmia laevigata (Brid.) Brid.: on the volcanic stones of the balcony of the Italian Garden.
Grimmia pulvinata (Hedw.) Sm.: on stone benches; on the volcanic stones of the balcony of the Italian Garden.
Grimmia trichophylla Grev.: on the volcanic stones of the balcony of the Italian Garden.
Gymnostomum calcareum Nees & Hornsch.: on stones of the Roman Amphitheatre.
Gyroweisia tenuis (Hedw.) Schimp.: on stones of the Roman Amphitheatre.
Habrodon perpusillus (De Not.) Limpr.: on bark of *Arbutus unedo*, *Cupressus sempervirens*, *Olea europaea* and *Quercus ilex.*
Homalothecium sericeum (Hedw.) Schimp.: on bark of *Olea europaea* and *Quercus robur.*
Hypnum cupressiforme Hedw. var. *cupressiforme*: on bark of *Olea europaea*, *Quercus ilex and Q. robur*; soil of the flowerbeds.
Hypnum cupressiforme var. *filiforme* Brid.: on bark of *Arbutus unedo.*
Kindbergia praelonga (Hedw.) Ochyra: on stones of *Opus reticulatum*; on soil of flowerbeds.

Leptodon smithii (Hedw.) F. Weber & D. Mohr: on bark of *Arbutus unedo*, *Olea europaea*, *Quercus ilex and Q. robur*; on stones of the *Nymphaeum.*

Leucodon sciuroides (Hedw.) Schwägr.: on bark of *Olea europaea*, *Quercus ilex and Q. robur.*

Microbryum rectum (With.) R. H. Zander: on soil of the Roman Amphitheatre.

Microeurhynchium pumilum (Wilson) Ignatov & Vanderp.: on soil of flowerbeds; on stones of *Opus reticulatum*; on damp slope.

Nogopterium gracile (Hedw.) Crosby & W. R. Buck: on bark of *Olea europaea* and *Quercus ilex.*

Orthotrichum diaphanum Schrad. *ex* Brid.: on bark of *Arbutus unedo.*

Orthotrichum lyellii Hook. & Taylor: on bark of *Olea europaea.*

Orthotrichum tenellum Bruch *ex* Brid.: on bark of *Arbutus unedo*, *Olea europaea*, *Quercus ilex.*

Oxyrrhynchium speciosum (Brid.) Warnst.: on stones of *Opus reticulatum.*

**Oxystegus tenuirostris* (Hook. & Taylor) A. J. E. Sm.: on basaltic stones.

Plagiomnium elatum (Bruch & Schimp.) T. J. Kop.: on soil of flowerbeds.

Plagiomnium medium (Bruch & Schimp.) T. J. Kop.: on soil of flowerbeds.

Plasteurhynchium meridionale (Schimp.) M. Fleisch.: on soil of flowerbeds.

**Pottiopsis caespitosa* (Bruch *ex* Brid.) Blockeel & A. J. E. Sm.: on soil of the Roman Amphitheatre.

Pseudocrossidium revolutum (Brid.) R. H. Zander: on soil of the Roman Amphitheatre.

Pseudoleskeella nervosa (Brid.) Nyholm: on bark of *Quercus ilex.*

**Ptychostomum boreale* (F. Weber & D. Mohr) Ochyra & Bednarek-Ochyra: on soil of flowerbeds; on basaltic stones.

Ptychostomum capillare (Hedw.) Holyoak & N. Pedersen: on stones of *Opus reticulatum*, Roman Amphitheatre and *Nymphaeum*; on soil of flowerbeds and on the vineyard.

Ptychostomum imbricatulum (Müll. Hal.) Holyoak & N. Pedersen: on soil of flowerbeds and on the vineyard; on stones of *Opus reticulatum.*

Rhynchostegiella tenella (Dicks.) Limpr.: on stones of *Opus reticulatum*, Roman Amphitheatre and *Nymphaeum*; on damp slope; on stones of the path of live oaks.

Rhynchostegium confertum (Dicks.) Schimp.: on soil of flowerbeds; on basaltic stones.

Rhynchostegium megapolitanum (Blandow *ex* F. Weber & D. Mohr) Schimp.: on soil of flowerbeds.

Scorpiurium circinatum (Bruch) M. Fleisch. & Loeske.: on soil and stones of the flowerbeds, Roman Amphitheatre, *Opus reticulatum* and *Nymphaeum*.

Syntrichia laevipila Brid.: on bark of *Arbutus unedo*, *Cedrus atlantica*, *Quercus ilex* and *Q. robur*; on basaltic rocks.

Syntrichia papillosa (Wilson) Jur.: on bark of *Olea europaea.*

Tortula atrovirens (Sm.) Lindb.: on rocks of the flowerbeds.

Tortula inermis (Brid.) Mont.: on bark of *Quercus ilex*; on stones of *Nymphaeum.*

Tortula marginata (Bruch & Schimp.) Spruce: on stones of *Nymphaeum.*

Tortula muralis Hedw.: on stones of the *Opus reticulatum*; on the volcanic stones of the balcony of the Italian Garden.

Tortula subulata Hedw.: on stones of the *Opus reticulatum* and Roman Amphitheatre.

**Zygodon forsteri* (Dicks.) Mitt.: on bark of *Olea europaea* and *Quercus ilex.*

Zygodon rupestris Lorentz: on bark of *Arbutus unedo*, *Cedrus atlantica*, *Cupressus sempervirens*, *Olea europaea, Quercus ilex.*

Discussion and conclusions

Among the species collected the finding of *Anthoceros agrestis*, is particularly interesting, since it is a Mediterranean temperate species, previously reported only for Campania (Thyssen 1965), Calabria (Aleffi & Puntillo 1998), Sicily (Lübenau R. & Lübenau K. 1970; Raimondo & Dia 1981; Privitera & Puglisi 1996; Privitera & al. 2008) and Sardinia (Frahm & al. 2008). This acidophytic-subneutrophytic species grows on open, compacted clay and loam and is known from the Algeria, Canary Islands, Crete, France, Madeira, Macedonia, Morocco and Portugal (Ros & al. 2007).

Another interesting finding is *Cynodontium bruntonii*. This species was reported for the regions of northern Italy and for Sicily (Blockeel 1995; Privitera & Puglisi 1996, 2002) and Sardinia (Aleffi & al. 1995; Frahm & al. 2008) and this is the only report for continental south-central Italy. It is a suboceanic-montane species that grows on siliceous rocks, with known locations in Europe, North Africa and Macaronesia (Dierβen 2001).

Pottiopsis caespitosa is a rare species in Italy, recently recorded only for some regions of south Italy: Apulia (Aleffi & al. 2009), Campania (Thyssen 1965; Mazzoleni & al. 1993), Calabria (Privitera & Puglisi 1999), Sicily (Lübenau R. & Lübenau K. 1970; Aiello & al. 2001; Carratello 2001, 2004) and Sardinia (Cortini Pedrotti & Aleffi 1994). This suboceanic-montane species is widespread in the Mediterranean basin and grows on bare and exposed soil.

Zygodon forsteri in Italy was recently recorded only in the Marche (Aleffi & al. 2005), Campania (Cipollaro & Colacino 2005), Sicily (Dia & Lo Re 2005) and Sardinia (Frahm & al. 2008). It is an oceanic-submediterranean *taxon* distributed in the European continent in Bulgaria, Croatia, France, Greece, Montenegro, Portugal, Serbia, Spain, and Turkey; outside Europe it is present in Cyprus, Israel, Madeira and Syria (Ros & al. 2013). The species grows on the trunks and exposed roots, in well-lighted sites and in conditions of moderate moisture. It is considered Vulnerable (V) in Europe (ECCB 1995); in the United Kingdom it has been included in the "*UK Biodiversity Action Plan*" and in the "*English Nature's Species Recovery Programme*" with the purpose of conservation and increase of the populations *in situ*. Though the pattern of distribution of this species is on the whole fairly widespread, in fact its presence is limited to only a few locations with very small populations.

The bryoflora of the Pontifical Villas of Castel Gandolfo is characterized by the presence of a substantial number of species with Oceanic-Mediterranean tendency, which are about 50% of the species collected in the study area, against 35% of temperate species and a nonetheless significant 15% of species with boreal tendency. This fact is doubtlessly related to the particular ecological and microclimatic conditions in the Pontifical Villas, due to diversity of habitats and the permanent conditions of humidity present in the entire area. Concerning the substratum, the volcanic nature of the entire territory causes conditions of marked acidity, both in the soil and in the outcropping rocks. This has a decisive influence on the composition of the species, about half of which are acidophilous and 35% subneutrophilous species, while typically basiphilous species are only 15% of the total species observed (Dierβen 2001).

The particular structure of the Pontifical Villas, characterized not only by traditional Italian-style gardens, but also by a fairly extensive area of farmland (olive groves, vineyards, fruit groves) and the substantial presence of archaeological ruins of the ancient Villa of Domitian (Amphitheatre, nymphaeums, etc.) have a significant influence on the bryophyte diversity and richness. Therefore, the bryophyte biodiversity of the Pontifical Villas is numerically high

Table 1. List of *taxa* found in both studied areas, indicating for each of them, chorotypes, growth substrate and life form. Life forms abbreviations: At: aquatic trailing; Cu: cushion; De: dendroid; Fa: fan; Mr: mat, rough; Ms: mat, smooth; Mt: mat, thalloid; Sc: solitary creeping; St: solitary thalloid; Tf: turf; Tp: turf, protonemal; Ts: turf, scattered; We: weft.

Taxa	Vatican Gardens	Pontifical Villas	Chorotypes	soil	rocks	epiphytes	Life Forms
Hornworts and Liverworts							
Anthoceros agrestis Paton		•	Temperate	•			St
Cephaloziella baumgartneri Schiffn.	•	•	Oceanic Mediterranean		•		Sc
Cephaloziella divaricata (Sm.) Schiffn.	•		Temperate		•		Ms
Chiloscyphus polyanthos (L.) Corda	•		Subboreal		•		At
Cololejeunea rossettiana (C. Massal.) Schiffn.		•	Submediterranean Montane			•	Mr
Conocephalum salebrosum Szweyk., Buczkowska & Odrzykoski	•	•	Subboreal Montane		•		Mt
Fossombronia angulosa (Dicks.) Raddi		•	Oceanic Mediterranean	•			Ms
Fossombronia caespitiformis Rabenh.	•	•	Oceanic Mediterranean	•			Sc
Frullania dilatata (L.) Dumort.	•	•	Temperate			•	Ms
Lejeunea cavifolia (Ehrh.) Lindb.		•	Suboceanic Montane		•	•	Ms
Lunularia cruciata (L.) Lindb.	•	•	Oceanic Mediterranean	•			Mt
Marchantia polymorpha subsp. *ruderalis* Bischl. & Boisselier	•	•	Temperate	•			Mt
Metzgeria furcata (L.) Dumort.	•	•	Temperate			•	Mt
Pellia endiviifolia (Dicks.) Dumort.	•	•	Temperate		•		Mt
Pellia epiphylla (L.) Corda	•		Temperate		•		Mt
Porella platyphylla (L.) Pfeiff.	•	•	Temperate			•	Fa
Radula complanata (L.) Dumort.	•	•	Temperate			•	Ms
Sphaerocarpos michelii Bellardi	•	•	Suboceanic Submediterranean	•			St
Targionia hypophylla L.		•	Oceanic Submediterranean	•	•		Mt
Mosses							
Alleniella besseri (Lobarz.) S. Olsson, Enroth & D. Quandt		•	Subcontinental Montane		•		Fa
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt		•	Temperate			•	Fa
Aloina rigida (Hedw.) Limpr.		•	Temperate	•			Ts
Amblystegium serpens (Hedw.) Schimp.	•	•	Temperate	•			Mr
Anomodon viticulosus (Hedw.) Hook. & Taylor	•		Temperate	•			Mr
Barbula bolleana (Müll. Hal.) Broth.	•		Submediterranean		•		Tf
Barbula convoluta Hedw.		•	Temperate	•			Tf
Barbula unguiculata Hedw.	•	•	Temperate	•	•	•	Tf
Brachythecium rivulare Schimp.	•		Subboreal		•		Mr
Brachythecium rutabulum (Hedw.) Schimp.	•	•	Temperate		•	•	Mr
Brachythecium salebrosum (F. Weber & D. Mohr) Schimp.		•	Subboreal	•			Mr
Bryum argenteum Hedw.	•	•	Temperate	•			Tf
Bryum dichotomum Hedw.	•		Temperate	•			Tf
Bryum elegans Nees		•	Boreal Montane	•			Tuft
Bryum gemmiparum De Not.	•		Suboceanic Submediterranean		•		Tuft
Bryum radiculosum Brid.	•		Suboceanic Mediterranean		•		Cu
Bryum ruderale Crundw. & Nyholm	•		Suboceanic	•			Tuft
Calliergonella cuspidata (Hedw.) Loeske	•		Temperate	•			We
Ceratodon purpureus (Hedw.) Brid.	•	•	Temperate		•		Tf
Cinclidotus aquaticus (Hedw.) Bruch & Schimp.	•		Submediterranean Montane		•		At
Cinclidotus fontinaloides (Hedw.) P. Beauv.	•		Submediterranean Montane		•		At
Ctenidium molluscum (Hedw.) Mitt.	•		Temperate	•			Mr
Cynodontium bruntonii (Sm.) Bruch & Schimp.		•	Suboceanic Montane		•		Cu
Dialytrichia mucronata (Brid.) Broth.	•		Submediterranean Suboceanic			•	Tuft
Dicranella howei Renauld & Cardot		•	Oceanic Mediterranean	•			Tuft
Dicranella varia (Hedw.) Schimp.	•		Temperate	•			Tf
Didymodon fallax (Hedw.) R. H. Zander	•		Temperate		•		Tf
Didymodon ferrugineus (Besch.) M. O. Hill	•		Temperate Montane		•		Tf
Didymodon insulanus (De Not.) M. O. Hill	•	•	Submediterranean Suboceanic		•		Tf
Didymodon luridus Hornsch.	•	•	Submediterranean	•	•		Tf
Didymodon rigidulus Hedw.		•	Temperate		•		Tuft
Didymodon sinuosus (Mitt.) Delogne	•	•	Suboceanic Submediterranean		•		Tf
Didymodon spadiceus (Mitt.) Limpr.	•		Temperate Montane		•	•	Tf
Didymodon tophaceus (Brid.) Lisa	•		Temperate	•	•		Tf
Didymodon vinealis (Brid.) R. H. Zander	•	•	Submediterranean	•	•		Tuft
Drepanocladus aduncus (Hedw.) Warnst.	•		Temperate		•		We
Enthostodon convexus (Spruce) Brugués		•	Mediterranean		•		Ts
Eucladium verticillatum (With.) Bruch & Schimp.	•	•	Submediterranean		•		Tuft

Table 1. continued.

Eurhynchiastrum pulchellum (Hedw.) Ignatov & Huttunen	•	•	Subboreal Montane	•		•	Mr
Eurhynchium striatum (Hedw.) Schimp.		•	Suboceanic		•		We
Fabronia pusilla Raddi	•	•	Submediterranean			•	Mr
Fissidens crassipes Bruch & Schimp.	•		Suboceanic Submediterranean		•		Tf
Fissidens crispus Mont.	•	•	Oceanic Mediterranean	•	•		Tf
Fissidens exilis Hedw.		•	Temperate		•		Ts
Fissidens ovatifolius R. Ruthe		•	Mediterranean Suboceanic	•			Tf
Fissidens pusillus (Wilson) Milde	•		Temperate Montane	•			Ts
Fissidens serrulatus Brid.	•		Oceanic Submediterranean	•			Tf
Fissidens viridulus (Sw.) Wahlenb. var. *viridulus*	•	•	Submediterranean		•		Tf
Fissidens viridulus var. *incurvus* (Röhl.) Waldh.	•	•	Submediterranean	•	•		Tf
Funaria hygrometrica Hedw.	•	•	Temperate	•			Tuft
Grimmia laevigata (Brid.) Brid.		•	Submediterranean Suboceanic		•		Cu
Grimmia lisae De Not.	•		Mediterranean Oceanic		•		Tf
Grimmia pulvinata (Hedw.) Sm.	•	•	Temperate		•		Cu
Grimmia trichophylla Grev.	•	•	Temperate Montane		•		Cu
Gymnostomum calcareum Nees & Hornsch.	•	•	Submediterranean Montane		•		Tf
Gymnostomum viridulum Brid.	•		Submediterranean Montane		•		Tf
Gyroweisia tenuis (Hedw.) Schimp.	•	•	Submediterranean Suboceanic		•		Tp
Habrodon perpusillus (De Not.) Lindb.	•	•	Mediterranean Oceanic			•	Mr
Hedwigia stellata Hedenäs	•		Subboreal Montane			•	Mr
Homalothecium lutescens (Hedw.) H. Rob.	•		Temperate	•			We
Homalothecium sericeum (Hedw.) Schimp.	•	•	Temperate		•	•	Mr
Hygroamblystegium fluviatile (Hedw.) Loeske	•		Suboceanic Montane		•		Mr
Hygroamblystegium tenax (Hedw.) Jenn.	•		Temperate		•		Mr
Hypnum cupressiforme Hedw. var. *cupressiforme*	•	•	Temperate	•	•	•	Ms
Hypnum cupressiforme var. *filiforme* Brid.	•	•	Temperate			•	Ms
Isothecium alopecuroides (Dubois) Isov.	•		Temperate	•			De
Kindbergia praelonga (Hedw.) Ochyra	•	•	Temperate		•		Mr
Leptodon smithii (Hedw.) F. Weber & D. Mohr	•	•	Oceanic Mediterranean		•	•	Fa
Leptodyctium riparium (Hedw.) Warsnt.	•		Temperate		•		Mr
Leucodon sciuroides (Hedw.) Schwägr.	•	•	Temperate			•	Mr
Microbryum rectum (With.) R. H. Zander		•	Oceanic Submediterranean	•			Ts
Microeurhynchium pumilum (Wilson) Ignatov & Vanderp.	•	•	Suboceanic Submediterranean	•	•		Mr
Nogopterium gracile (Hedw.) Crosby & W. R. Buck	•	•	Suboceanic Submediterranean			•	Mr
Orthotrichum acuminatum H. Philib.	•		Submediterranean Montane			•	Cu
Orthotrichum affine Schrad. *ex* Brid.	•		Temperate			•	Cu
Orthotrichum diaphanum Brid.	•	•	Temperate		•	•	Cu
Orthotrichum lyellii Hook. & Taylor	•	•	Euoceanic Montane			•	Tuft
Orthotrichum speciosum Nees	•		Temperate			•	Cu
Orthotrichum stramineum Brid.	•		Suboceanic			•	Cu
Orthotrichum tenellum Bruch *ex* Brid.	•	•	Submediterranean Suboceanic			•	Cu
Oxyrrhynchium hians (Hedw.) Loeske	•		Temperate	•			Mr
Oxyrrhynchium speciosum (Brid.) Warnst.	•	•	Temperate		•		Mr
Oxystegus tenuirostris (Hook. & Taylor) A. J. E. Sm.		•	Suboceanic Montane		•		Tf
Philonotis calcarea (Bruch & Schimp.) Schimp.	•		Subboreal		•		Tf
Philonotis fontana (Hedw.) Brid.	•		Subboreal		•		Tf
Philonotis marchica (Hedw.) Brid.	•		Submediterranean		•		Tf
Philonotis rigida Brid.	•		Oceanic Mediterranean		•		Tf
Plagiomnium elatum (Bruch & Schimp.) T. J. Kop.	•	•	Boreal	•			Tf
Plagiomnium medium (Bruch & Schimp.) T. J. Kop.	•	•	Subarctic Alpine	•			Ms
Plagiomnium rostratum (Schrad.) T. J. Kop.	•		Temperate	•			Ms
Plagiomnium undulatum (Hedw.) T. J. Kop.	•		Temperate	•			Tf
Plasteurhynchium meridionale (Schimp.) M.Fleisch.		•	Suboceanic Mediterranean	•			Mr
Pohlia melanodon (Brid.) A. J. Shaw	•		Temperate		•		Tf
Pohlia wahlenbergii (F. Weber & D. Mohr) A. L. Andrews	•		Subboreal		•		Tf
Pottiopsis caespitosa (Bruch *ex* Brid.) Blockeel & A. J. E. Sm.		•	Submediterranean Suboceanic	•			Ts
Pseudocrossidium revolutum (Brid.) R. H. Zander		•	Oceanic Submediterranean	•			Tf
Pseudoleskeella catenulata (Brid. *ex* Schrad.) Kindb.	•		Boreal Montane			•	Mr
Pseudoleskeella nervosa (Brid.) Nyholm	•	•	Boreal Montane		•	•	Mr
Pseudoscleropodium purum (Hedw.) M. Fleisch.	•		Temperate	•			We
Ptychostomum boreale (F. Weber & D. Mohr) Ochyra & Bednarek-Ochyra		•	Temperate	•	•		Tuft
Ptychostomum capillare (Hedw.) D. T. Holyoak & N. Pedersen	•	•	Temperate	•	•	•	Tf
Ptychostomum donianum (Grev.) D. T. Holyoak & N. Pedersen	•		Oceanic Mediterranean		•		Tf
Ptychostomum imbricatulum (Müll. Hal.) D. T. Holyoak & N. Pedersen	•	•	Temperate		•		Tf
Ptychostomum pallens (Sw.) J. R. Spence	•		Boreal		•		Tf
Ptychostomum pseudotriquetrum (Hedw.) J. R. Spence & H. P. Ramsay	•		Temperate		•		Tf
Ptychostomum torquescens (Bruch & Schimp.) Ros & Mazimpaka	•		Oceanic Mediterranean	•			Tf
Rhynchostegiella curviseta (Brid.) Lindb.	•		Submediterranean Suboceanic		•	•	Ms

Table 1. continued.

Rhynchostegiella tenella (Dicks.) Limpr.	•	•	Submediterranean Suboceanic	•	•	•	Mr
Rhynchostegium confertum (Dicks.) Schimp.	•	•	Submediterranean Oceanic	•	•		Mr
Rhynchostegium megapolitanum (F. Weber & D. Mohr) Schimp.	•	•	Suboceanic Mediterranean	•	•		Mr
Rhynchostegium riparioides (Hedw.) Cardot	•		Temperate		•		Ms
Sciuro-hypnum plumosum (Hedw.) Ignatov & Huttunen	•		Suboceanic			•	Mr
Scorpiurium circinatum (Bruch) M. Fleisch & Loeske	•	•	Oceanic Mediterranean	•	•	•	Mr
Syntrichia laevipila Brid.	•	•	Oceanic Submediterranean	•	•	•	Tf
Syntrichia papillosa (Wilson) Jur.	•	•	Temperate			•	Tuft
Syntrichia ruralis (Hedw.) F. Weber & D. Mohr var. *ruralis*	•		Temperate		•		Tf
Tortella inflexa (Bruch) Broth.	•		Oceanic Mediterranean		•		Tp
Tortella nitida (Lindb.) Broth.	•		Oceanic Mediterranean	•	•		Cu
Tortula atrovirens (Sm.) Lindb.		•	Submediterranean		•		Tf
Tortula bolanderi (Lesq. & James) M. Howe	•		Oceanic Mediterranean		•		Tf
Tortula canescens Mont.	•		Suboceanic Mediterranean		•		Tf
Tortula inermis (Brid.) Mont.		•	Submediterranean Montane		•	•	Tf
Tortula marginata (Bruch & Schimp.) Spruce	•	•	Oceanic Mediterranean		•		Tf
Tortula muralis Hedw.	•	•	Temperate		•		Tf
Tortula subulata Hedw.	•	•	Subboreal Montane	•			Tuft
Trichostomum brachydontium Bruch	•		Suboceanic Mediterranean	•			Tf
Trichostomum crispulum Bruch	•		Temperate	•	•		Tf
Weissia condensa (Voit) Lindb.	•		Suboceanic Mediterranean		•		Tf
Zygodon forsteri (Dicks.) Mitt.		•	Euoceanic Submediterranean			•	Cu
Zygodon rupestris Lorentz	•	•	Suboceanic Mediterranean		•	•	Tf

when compared with the data emerged from similar studies conducted in the gardens and parks of the urban area of Rome (Carcano 1989) and in some cities of Sicily (Dia & al. 2003).

Considering the area of the Vatican Gardens, which covers about 44 hectares, and that of the gardens of the Pontifical Villas of Castel Gandolfo, which extends for about 55 hectares, the study of the bryoflora of the territory of the Vatican City State covers about 100 hectares. Taken together, the two studies noted 149 *taxa* which are about 12.5% of the Italian flora, a significant percentage if one considers the modest extension of the territory studied. Of these, 1 hornworts, 1 liverworts and 16 mosses are new records for the Lazio Region.

On the basis of the substratum most of the species were collected on rocks (87 species), followed by terricolous species (57 species), while the epiphytes are 40. Most of the latter are species that grow exclusively on the bark of trees, such as *Fabronia pusilla*, *Habrodon perpusillus*, *Nogopterium gracile* and the species of the *Orthotrichum* genus.

Finally, it was considered the overall distribution of life-forms of the species (Hill & al. 2007), showing a clear dominance of turf (35%) and mats (32%), while tufts and cushion respectively represent around 10% of the total. It also reveals a clear distinction between exposed sites (e.g. flowerbeds and exposed rocks), characterized by high insolation and drier conditions, where life-forms as cushions (e.g. *Grimmia* and *Orthotrichum* species), tufts and turfs (e.g. *Didymodon*, *Philonotis*, *Ptychostomum* and *Tortula* species) dominate, and shaded sites, (e.g. the fountains and the archaeological remains, or areas with high tree cover), where rough mats (e.g. *Brachythecium* species and *Homalothecium sericeum*), smooth mats (e.g. *Frullania dilatata* and *Hypnum cupressiforme*), thalloid mats (e.g. *Conocephalum salebrosum* and *Metzgeria furcata*), fans (e.g. *Alleniella besseri*, *A. complanata*, *Leptodon smithii*, *Porella platyphylla*) and wefts (e.g. *Calliergonella cuspidata* and *Pseudoscleropodium purum*) prevail, thus clearly confirming the results of other studies (Kürschner 2004; Sérgio & al. 2014; Puglisi & al. 2013, 2014, 2015; Dia & Campisi 2015).

The study of the bryoflora of the Vatican City State contributes significantly to the knowledge of a territory which until now had been scarcely explored from the bryological

point of view, and provides important floristic information for the realization and definition of the Checklist and country status of European Bryophytes (Rossi & al. 2014; Sérgio & al. 2014; Hodgetts 2015).

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