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FLORA OF THE MINERAL CO_2-SPRING «BOSSOLETO» (RAPOLANO TERME, TUSCANY) AND ITS RELEVANCE TO ECOLOGICAL RESEARCH

Abstract - The flora occurring within the bowl-like mineral spring of carbon dioxide called «Bossoleto» near Rapolano Terme (Siena) is here reported. This biotope is currently considered most promising for studying the long-term effects of elevated atmospheric CO_2 on natural vegetation. The native vascular flora includes 92 species belonging to 81 genera and 45 families, distributed over a surface of about 5000 m^2. The presence of *Buxus sempervirens* L., from which the site takes its name, is particularly worth of note. The biological spectrum highlights large proportions of hemicryptophytes, therophytes and phanerophytes. From a chorological viewpoint the europeo-mediterranean and mediterranean species are the most represented. This flora offers a wide range of opportunities for further ecological research thanks to its taxonomic, chorological and structural diversity.

Key words - *Buxus sempervirens,* CO_2-springs, Elevated CO_2, Geothermal biotopes, Tuscan flora.

Riassunto - *Flora della sorgente minerale di CO_2 «Bossoleto» (Rapolano Terme, Toscana) ed il suo significato nella ricerca ecologica.* Nel presente contributo si riporta la composizione del popolamento floristico di un piccolo bacino geotermico con intensa emissione di anidride carbonica detta «Bossoleto», localizzata nei pressi di Rapolano Terme (Siena). Tale biotopo suscita attualmente un notevole interesse nella comunità scientifica grazie alla rara opportunità che esso offre per lo studio in natura degli effetti di alte concentrazioni atmosferiche di CO_2 su vegetazione spontanea da lungo tempo esposta a tale condizione. La flora del sito include 92 specie spontanee distribuite in 81 generi e 45 famiglie, su una superficie di circa 5000 m^2. Di particolare interesse risulta la presenza, verosimilmente spontanea, di *Buxus sempervirens* L., da cui il luogo prende il nome. Lo spettro biologico evidenzia la presenza di numerose emicriptofite, terofite e fanerofite, mentre quello corologico mostra la prevalenza di specie europeo-mediterranee e mediterranee. Viene messo in evidenza l'ampio spettro di possibilità di ricerca sulle risposte delle piante all'alta CO_2 offerto da una flora così diversificata in termini tassonomici, coroecologici e strutturali.

Parole chiave - Alta CO_2, Biotopi geotermici, *Buxus sempervirens,* Flora Toscana, Sorgenti di CO_2.

INTRODUCTION

The western regions of peninsular Italy are very rich in surface geothermal manifestations which are connected to residual volcanic activity or to the presence of deep consolidating magmas with a relatively high radioactivity (Panichi and Tongiorgi, 1975; Duchi *et al.*, 1985). In this area geothermal anomalies frequently cause surface phenomena like hot water springs and gaseous emissions (Baldi *et al.*, 1974). According to the composition and to the temperature of the emitted gases, three main types of geothermal sites can be conveniently distinguished: the «mofettes» (or mineral CO_2 springs), the «soffioni» and the «solfataras» (Poli, 1970). The gas emitted from the mofettes generally escapes at ambient temperature and is mainly composed of carbon dioxide (90-97% by volume), small amounts of methane (2.6%), nitrogen (5.2%) and sometimes traces of hydrogen sulphide (Duchi *et al.*, 1985). Igneous emanation, metamorphism of carbonates and solution of limestones by ground waters, represent the main mechanism of CO_2 inorganic origin. Geothermal sites have been known since Von Faber (1925) to represent peculiar habitats for plant life, due to several edaphic and atmospheric anomalies caused by the geothermal activity (Poli, 1970). This is the reason of the inclusion of the «very extreme environment of the fumaroles, which are colonized by paucispecific but highly distinct biological communities» among the relevant habitats of the European Community (Corine Biotopes Manual, 1991). Recently, the scientific community has realised that sites with natural emissions of carbon dioxide provide an unique opportunity for research into long-term effects of CO_2 on biological systems (Woodward *et al.*, 1991; Miglietta *et al.*, 1993; Miglietta *et al.*, 1995; van Gardingen *et al.*, 1995; Grace and van Gardingen, 1997; Bettarini *et al.*, 1998). A survey of CO_2 vents in Italy (Miglietta *et al.*, 1993), led to identify several sites well suited for physioecological researches on plants under chronically elevated levels of atmospheric CO_2. The attraction of these sites is that vegetation has been exposed to elevated CO_2 for long periods, allowing time for acclimation and possibly genetic adaptation. The great realism of such natural sites for experiments on plant-CO_2 relationships compared to laboratory studies or manipulative experiments have caused them to become one of the major topics of the current ecological research (Körner and Miglietta, 1994). Although most of the geothermal sites existing in Italy are currently exploited for industrial CO_2 mining or energy production, so that the natural vegetation is in many cases largely altered by human activities, some still exist where the spatial arrangement and the native species composition of plant communities around the gas-vents are still recognizable (Selvi, 1997). The Bossoleto spring in Central Tuscany was

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considered most promising at this regard because of the presence of natural vegetation exposed to physiologically relevant concentrations of CO_2 during the day, averaging between 600 and 1200 µmol mol^{-1} (van Gardingen *et al.*, 1995). Ecological research at this site has been in progress since 1992 (Miglietta *et al.*, 1993; Körner and Miglietta, 1994; Miglietta *et al.*, 1995; Tognetti *et al.*, 1995; Johnson *et al.*, 1997; Paoletti *et al.*, 1997; Bettarini *et al.*, 1998) and results produced are consistent with those obtained in short-term experiments (van Gardingen *et al.*, 1995). Consequently the Bossoleto spring has become in the recent years a site of international interest, visited by numerous botanists and researchers. Despite their interests on different aspects of plant life, most of them have stressed the need of data on the floristic composition of the vegetation and its biological and chorological features, to plan experimental design and sampling strategies. Consequently, a floristic survey of the site was carried out in order to provide a basis for further research and to illustrate the wide range of opportunities that the Bossoleto florula offers in terms of taxonomic, chorological and structural diversity.

THE CO_2-SPRING «BOSSOLETO»

Several springs vent out in the area of Rapolano Terme, about 40 Km south-east from the city of Siena, along the major line of tectonic discontinuity dividing the mesozoic rocks from the neogenic sands and clays of the Siena basin (Francalanci, 1959; Etiope and Lombardi, 1997). From a climatic viewpoint, the area is characterized by a submediterranean climate with mean annual rainfall of 833 mm and a mean temperature of 13.8 °C. Following Thornthwaite and Mather (1957), the local climate can be classified as second mesotermic (B'2), from humid to subhumid (C2) with slight summer water deficit (s) of suboceanic type (b'4). From a geological viewpoint the Rapolano area consists of mesozoic rocks, mostly of calcareous nature. The Bossoleto site is located on a travertine deposit formed in a calcareous basin dating back to the lower Lias. This mineral CO_2 spring (Lat. 43°17', Long. 11°35') is a circular crateric depression of about 80 m in diameter and 20 m deep (Fig. 1), which was formed when an underground cavern collapsed several hundred years ago. This bowl-like doline is surrounded by a middle-age wall that has reduced factors of human disturbance, though the site is locally known for fatal accidents. Gas emissions at this site have locally been known at least back to the early 19th century (Targioni-Tozzetti, 1835; de Launay, 1899), but probably dates back much longer, given the large travertine deposits from geothermal water. CO_2 emissions come out from several vents distributed on the bottom of the crater and from a large cave located at the bottom of the bowl towards the South of the site. A cross-section diagram showing relationships

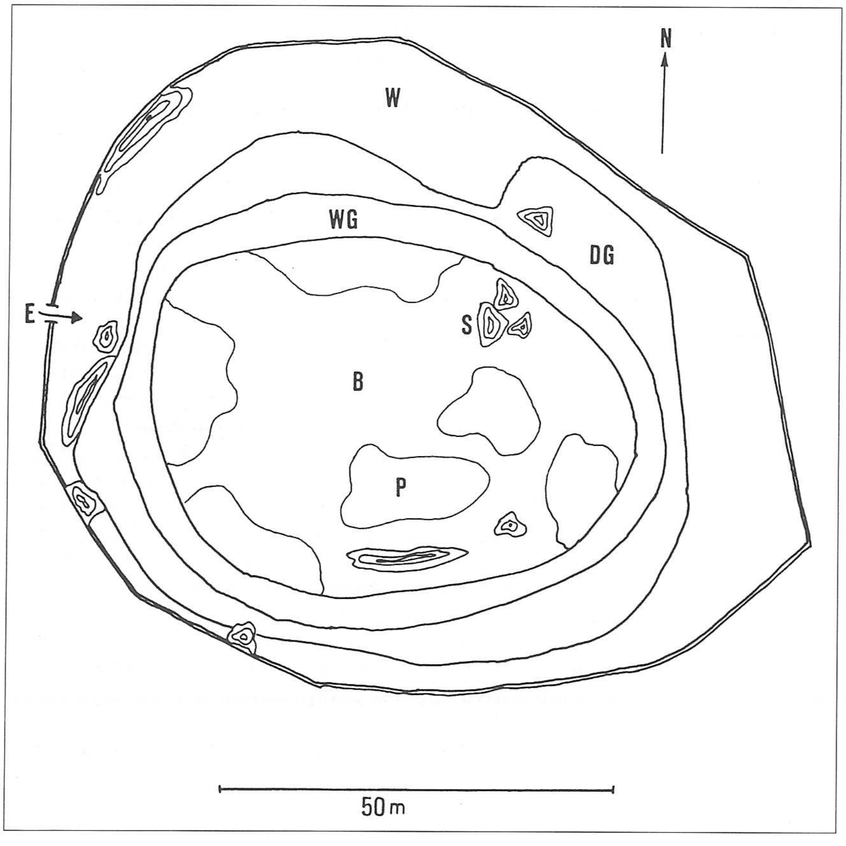

Fig. 1 - Map of the Bossoleto CO_2-spring showing topography and main habitat types: E entrance, W woodland, DG dry grassland, WG humid grassland, P *Phragmites australis* stands, S travertine stones, B bottom of the crater; contour lines represent about 4 m height.

between CO_2 concentrations, topography and main habitat types is shown in Fig. 2. The CO_2 from the vents is over 99% pure (van Gardingen *et al.*, 1997) and creates a steep concentration gradient along the raised banks of the site, where natural vegetation occurs. Mean daytime levels of CO_2 normally range between 500 and 1000 ppm, thus simulating a situation forecast to occur globally within the next 200 years (Körner and Miglietta, 1994). Although traces of hydrogen sulphide have been detected accompanying the CO_2 venting at the surface, this gas is largely dissolved in water vapour, is rapidly oxidised when in contact with air, and finally greatly diluted (Miglietta *et al.*, 1993). Temperature within the basin shows a rapid increase in the early morning associated with the presence of stable atmospheric conditions at the bottom of the bowl. This heating results from an enhanced greenhouse effect induced by a CO_2 concentration that can reaches 75% of the atmospheric gas at the bottom of the dolin (van Gardingen *et al.*, 1995).

Data on chemical composition of the soils of the Bossoleto basin were published elsewhere (Körner and Miglietta, 1994). At the bottom of the bowl there is a thick layer of blackish undecayed litter with pH about 7.6 due to the calcium carbonate released by the calcareous parent rock. Here, the water table is close to the soil surface and roots of *Phragmites australis* are in contact with a saturated salt solution at 38 °C. The ionic composition of the water mainly comprises the cations Ca^{2+}, Mg^{2+}, Na^{+} and the anions HCO_3^-, SO_4^{2-} and Cl^-(van Gardingen *et al.*, 1997). The lower banks consist of a stony calcareous soil with numerous travertine outcrops. On the upper banks under wood canopy there is a brown forest soil with a fair humus content.

FLORISTIC STUDY

Field surveys were carried out during spring-summer 94-95. Identification of specimens (now at the IATA-CNR, Firenze) was mainly based on national and international standard floras (Pignatti, 1982; Tutin *et al.*, 1964-80). Nomenclature follows in the order Med-Checklist (Greuter *et al.*, 1984-89), Flora Europaea (Tutin *et al.*, 1964-80; 1993) and Flora d'Italia (Pignatti, 1982). Systematic ordering of the floristic list follows Cronquist (1981) for the Magnoliopsida and Dahlgren *et al.* (1985) for the Liliopsida. Genera and species are in alphabetical order. Biological forms are expressed following Raunkiaer's classification (1934). Chorological types were defined following the phytogeographical synthesis by Takhtajan (1986) for the choronomic units above the regional rank and Arrigoni (1973; 1983) for the lower units of the European region. For each species, the main habitat type within the site has been indicated following the zonation in three sectors with increasing distance from the bottom (Fig. 2). Species recently introduced for experiments and now found as occasional adventive weeds were not considered in the floristic survey. Species sampled in previous or current ecophysiological studies are marked with *.

FLORISTIC LIST

ASPLENIACEAE

Asplenium ruta-muraria L. - Hros - Boreal-Oromediterranean - 3.

Asplenium trichomanes L. subsp. *trichomanes* - Hros - Subcosmopolitan - 2,3.

CUPRESSACEAE

Juniperus communis L. - Pcaesp - Holarctic - 3.

PAPAVERACEAE

Papaver rhoeas L. subsp. *rhoeas* - Tscap - Tethyan-European - 2.

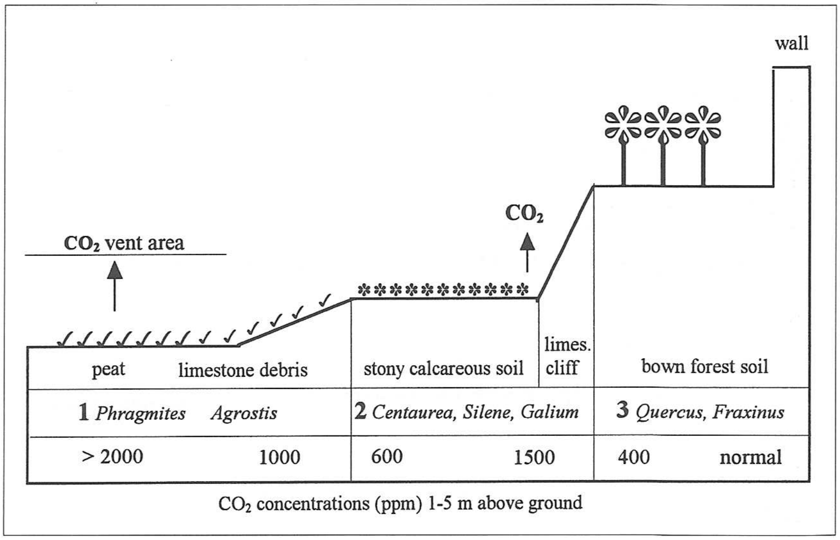

Fig. 2 - Cross-section diagram showing relationships between topography, CO_2 concentration gradient and main habitat types along the NE sector of the dolin.

FUMARIACEAE

Fumaria capreolata L. - Tscap - Mediterranean-Atlantic - 2.

Fumaria officinalis L. - Tscap - Mediterranean-Eurosiberian - 2.

URTICACEAE

Parietaria judaica L. - Hscap - Tethyan-European - 3.

FAGACEAE

* *Quercus ilex* L. - Pscap - Mediterranean - 3.

* *Quercus pubescens* Willd. - Pscap - C.Mediterranean-Pontic - 3.

BETULACEAE

Ostrya carpinifolia Scop. - Pscap - European - 2.

CARYOPHYLLACEAE

Arenaria leptoclados (Rchb.) Guss. - Tscap - Mediterranean-European - 2.

Cerastium ligusticum Viv. - Tscap - C.W.Mediterranean - 2.

Cerastium semidecandrum L. - Tscap - Tethyan - 2.

Moehringia trinervia (L.) Clairv. subsp. *pentandra* (Gay) Nyman - Tscap - Mediterranean - 3.

Petrorhagia saxifraga (L.) Link subsp. *saxifraga* - Hscap - Mediterranean - 2.

Silene italica (L.) Pers. - Hscap - Tethyan-European - 2.

Silene latifolia L. subsp. *alba* (Mill.) Greuter & Burdet - Hscap - Boreal-Tethyan - 2.

* *Silene vulgaris* (Moench) Garcke subsp. *angustifolia* (Mill.) Hayek - Hscap - Mediterranean - 2.

CLUSIACEAE

* *Hypericum perforatum* L. - Hscap - Tethyan-Eurosiberian - 2.

MALVACEAE

Malva sylvestris L. - Hscap - Tethyan-Eurosiberian - 3.

CISTACEAE

Cistus creticus L. subsp. *eriocephalus* (Viv.) Greuter & Burdet - NP - Mediterranenan-Pontic - 3.

* *Helianthemum apenninum* (L.) Miller - Chsuffr - Mediterranenan-European - 2.

SALICACEAE

Populus tremula L. - Pscap - Boreal-OroMediterranean - 2.

BRASSICACEAE

* *Arabidopsis thaliana* (L.) Heynh. - Tscap - Tethyan-Eurosiberian - 2.

* *Arabis hirsuta* (L.) Scop. - Hscap - Holarctic - 2,3.

Cardamine hirsuta L. - Tscap - Cosmopolitan - 2.

Erophila verna L. subsp. *praecox* (Steven) P. Fourn. - Tscap - Tethyan-Pontic - 2.

RESEDACEAE

Reseda phyteuma L. - Hscap - Mediterranean - 2.

ERICACEAE

Erica scoparia L. - Pcaesp - W.Mediterranean-Atlantic - 3.

PRIMULACEAE

Cyclamen repandum Sibth. & Sm. - Gbulb - Mediterranean - 3.

CRASSULACEAE

Sedum album L. - Chsucc - Mediterranean-European - 2.

SAXIFRAGACEAE

Saxifraga tridactylites L. - Tscap - Mediterranean-European - 2.

ROSACEAE

Prunus spinosa L. - NP - Mediterranean-European - 3.

Rosa sempervirens L. - Plian - Mediterranean-Atlantic - 3.

Rubus ulmifolius Schott. - NP - C.W.Mediterranean-Atlantic - 3.

* *Sanguisorba minor* Scop. - Hscap - Tethyan-European - 1,2.

LEGUMINOSAE

Anthyllis vulneraria L. subsp. *rubriflora* (DC.) Arcang. - Hscap - Mediterranean - 2.

Dorycnium hirsutum (L.) Ser. - Chsuffr - Mediterranean - 3.

* *Hippocrepis comosa* L. - Hscap - Mediterranenan-European - 2.

Hippocrepis emerus (L.) Lassen subsp. *emeroides* (Boiss. et Spruner) - NP - Mediterranean - 2.

Lathyrus sphaericus Retz. - Tscap - Mediterranean-European - 2.

Trifolium stellatum L. - Tscap - Mediterranean-Pontic- 2.

Vicia sativa L. subsp. *nigra* (L.) Ehrh. - Tscap - Tethyan - 2.

CORNACEAE

Cornus sanguinea L. - Pcaesp - European - 2,3.

SANTALACEAE

Osyris alba L. - NP - Mediterranean-European - 3.

BUXACEAE

* *Buxus sempervirens* L. - Pcaesp - European - 3.

RHAMNACEAE

Rhamnus catharticus L. - Pcaesp - Tethyan-Eurosiberian - 3.

SIMARUBACEAE

* *Ailanthus altissima* (Mill.) Swingle - Pscap - Adventive - 2.

GERANIACEAE

Geranium pusillum L. - Tscap - Tethyan-European - 2.

Geranium robertianum L. - Hscap - Tethyan-European - 3.

ARALIACEAE

Hedera helix L. - Plian - Mediterranean-European - 3.

APIACEAE

Daucus carota L. subsp. *carota* - Hbienn - Holarctic-Paleotropicale - 2.

CONVOLVULACEAE

* *Convolvulus cantabrica* L. - Hscap - Mediterranean-European - 3.

CUSCUTACEAE

Cuscuta epythymum (L.) L. subsp. *kotschyi* (Desmoulins) Arcang. - Tpar - Mediterranean - 2.

BORAGINACEAE

* *Echium vulgare* L. - Hbienn - Tethyan-Eurosiberian - 2.

Lithospermum arvense L. - Tscap - Tethyan-Eurosiberian - 2.

LAMIACEAE

Lamium amplexicaule L. - Tscap - Tethyan-Europeann - 3.

Satureja graeca L. - Chsuffr - Mediterranean - 2.

Sideritis romana L. - Tscap - Mediterranean - 2.

* *Stachys recta* L. subsp. *recta* - Hscap - Mediterranean-European - 2.

Teucrium chamaedrys L. - Hscap - Mediterranean-European - 3.

* *Teucrium montanum* L. - Chsuffr - Oromediterranean-MidEuropean- 2.

PLANTAGINACEAE

* *Plantago lanceolata* L. - Hros - Tethyan-Eurosiberian - 1,2.

OLEACEAE

* *Fraxinus ornus* L. - Pscap - Mediterranean-MidEuropean - 3.

Ligustrum vulgare L. - NP - European - 3.

SCROPHULARIACEAE

Cymbalaria muralis (Gaertn.) Meyer et Scherb. - Hscap - MidEuropean - 3.

Veronica hederifolia L. - Tscap - Mediterranean-European - 2.

GLOBULARIACEAE

* *Globularia punctata* Lapeyr. - Hros - Mediterranean-European - 2.

CAMPANULACEAE

Campanula erinus L. - Tscap - Tethyan - 2.

RUBIACEAE

Galium aparine L. - Tscap - Holarctic - 3.

* *Galium corrudifolium* Vill. - Hscap - Mediterranean - 2.

Rubia peregrina L. - Plian - Mediterranean-Atlantic - 3.

Sherardia arvensis L. - Tscap - Mediterranean-European - 2.

CAPRIFOLIACEAE

Lonicera etrusca Santi - Plian - Mediterranean - 3.

VALERIANACEAE

Valerianella carinata Loisel. - Tscap - Mediterranean-European - 2.

DIPSACACEAE

* *Scabiosa columbaria* L. - Hscap - Holarctic-Paleotronical - 2.

ASTERACEAE

Anthemis tinctoria L. - Hbienn - Eurosiberian - 2.

* *Centaurea deusta* Ten. subsp. *deusta* - Hscap - Appenninic-Balcanic - 1,2.

Helichrysum italicum (Roth) Don. - Chsuffr - Mediterranean - 2.

Hieracium piloselloides Vill. - Hscap - Mediterranean-European - 3.

Hypochoeris achyrophorus L. - Tscap - Mediterranean - 2.

Picris echioides L. - Tscap - Mediterranean-Atlantic - 2.

Reichardia picroides (L.) Roth - Hscap - Mediterranean - 2.

Urospermum dalechampii (L.) Schmidt - Hros - C.W.Mediterranean - 3.

RUSCACEAE

* *Ruscus aculeatus* L. - Grhiz - Mediterranean-European - 3.

ALLIACEAE

Allium carinatum L. subsp. *pulchellum* Bonnier et Layens - Gbulb - Mediterranean - 2.

Allium sphaerocephalon L. - Gbulb - Mediterranean-European - 2.

ORCHIDACEAE

Ophrys sphegodes Miller subsp. *sphegodes* - Grhiz (tub) - Mediterranean-European - 3.

CYPERACEAE

Scirpus holoschoenus L. - Grhiz - Tethyan-Eurosiberian - 2.

POACEAE

Agrostis stolonifera L. - Hrept - Boreal-Tethyan - 1,2.

Festuca inops De Not. - Hcaesp - Appenninic (Endem.) - 2.

Melica ciliata L. - Hcaesp - Mediterranean-European - 2.

Phragmites australis (Cav.) Trin. ex Steud. - Grhiz - Holarctic-Paleotropical - 1.

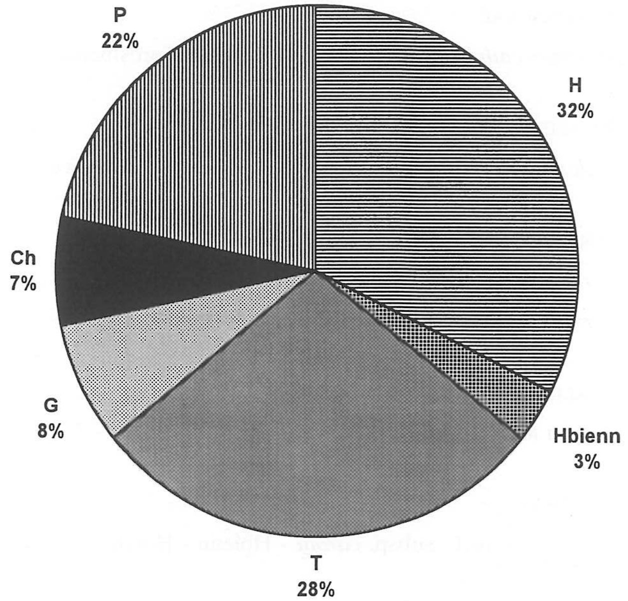

Fig. 3 - Biological spectrum: **P** phanerophytes, **T** therophytes, **H** hemycriptophytes, **Hbienn** biennal hemicryptophytes, **G** geophytes, **Ch** chamaephytes.

DISCUSSION

The native flora of the Bossoleto site is rather rich in respect to its surface, including 92 species, 81 genera and 45 families of vascular plants distributed over about 5000 m^2. It is especially worth of note the taxonomic diversity of higher rank, expressed by genera/species and families/genera ratios of 0.88 and 0.55, respectively. Unfortunately, also several ruderal and synanthropic species are currently present, due to past horticultural activities and to soil introductions for experimental research. There are no particularly rare species, except perhaps *Buxus sempervirens* from which the site takes its name. Within the dolin, this plant is sparsely localized on travertine slopes under forest canopy, where it appears to be a native element of the shrub layer. It is probably a residue of formerly larger populations occurring in the understory of the *Q. ilex* woodlands on travertine rocks once surrounding the site. In peninsular Italy, *B. sempervirens* shows a strongly fragmented distribution (Pignatti, 1982), and in Tuscany it occurs as a native species in the xeric *Quercus* woods on mesozoic limestones around Bagni di San Filippo and Sarteano, south of Siena, and in the mesic forests in the basin of the Merse river (Giacchi, 1976; Angiolini and de Dominicis, 1998).
From a biological viewpoint, the flora shows a Raunkiaer's life-forms spectrum (Fig. 3) characterised by a prevalence of hemicryptophytes and therophytes. According to the classification by Sabato and Valenziano (1975), the ratio of these two life-forms, 1.1, reflects a mesomediterranean bioclimate approaching the subcontinental threshold. Therophytes with a short life-cycle *(Cerastium ligusticum, Saxifraga tridactylites, Sideritis romana),* are mostly confined to the south-facing slopes with travertine outcrops, where an herbaceous xerocalcicolous community occur. Several mediterranean species of this community type have recently been shown (Körner and Miglietta, 1994) to accumulate non-structural carbohydrates and to dilute nitrogen, a phenomenon which is likely to become a reality in a CO_2 enriched future biosphere.
Hemicryptophytes are prevalent in all the habitat types within the site, forming the understory of the forest community as well as the herbaceous, humid vegetation ringing the bottom of the crater. In the latter, species diversity is much lower than that normally occurring in lighty, humid habitats with a neutral soil, due to frequent CO_2 flooding that induces atmospheric and edaphic anoxia and a marked green-house effect which causes in the summer very high temperatures in the air and on surfaces of leaves (van Gardingen *et al.*, 1995). This herbaceous community is strongly dominated by an hexaploid cytotype of *Agrostis stolonifera* (Selvi, unpublish. data), an entity which has been observed in other Tuscan gas-springs with calcareous soils since the time of Santi (1795). *A. stolonifera* can be considered as an ecological vicariant of *Agrostis canina L.* subsp. *monteluccii,* the dominant species of the pioneer vegetation of solfataras with hyperacid soils and high content of soluble Aluminium (Fiorini *et al.*, 1993; Selvi, 1994; Selvi, 1997). A similar ecological role is played by *A. castellana,* in the constitution of the community colonizing the heated and acid soils of the Tuscan «Soffioni Boraciferi» (Fiori, 1921). These data add evidence on the capacity of some *Agrostis* species to select populations able to colonize hostile environments, such as lead and zinc poisoned soils or galvanized fences (Bradshaw, 1952, 1965; Wu *et al.*, 1971).
The forest vocation of the site is shown by the richness of the phanerophytic component, that includes shrubs, small and large trees with different ecology. The hygrophytic *Populus tremula* and the mesoxerophytic *Ostrya carpinifolia* are rooted in the bottom of the dolin, while

true xerophytic species dominate on the high banks where they form a fragment of mediterranean wood. Individuals of *Q. ilex* and *Q. pubescens* of the Bossoleto have been widely sampled for measuring leaf gas exchanges (Van Gardingen *et al.*, 1997), water stress under elevated CO_2 (Tognetti *et al.*, 1995), leaf metabolism (Chaves *et al.*, 1995) stomatal density (Paoletti *et al.*, 1997; van Gardingen *et al.*, 1997) and isoprene emission (Johnson *et al.*, 1997).

Chorological diversity of the Bossoleto flora is also remarkable, with 25 choronomic units representing 27.1% of the flora. The more similar of them have been grouped in order to obtain a simplified chrological spectrum (Fig. 4). This shows that the Mediterranean-European species s.l. are the most represented, along with conspicuous proportions of Mediterranean and Tethyan species. This confirms that the chorological barycentre of the flora lies in the mesomediterranean area, consistently with the local climatic features and with the biological spectrum. The Mediterranean-Atlantic species prevail over the Mediterranean-Pontic, indicating a stronger affinity with the western sector of the basin. Species with a large distribution are also well represented, while there is only one endemism with a apenninic range *(Festuca inops).*

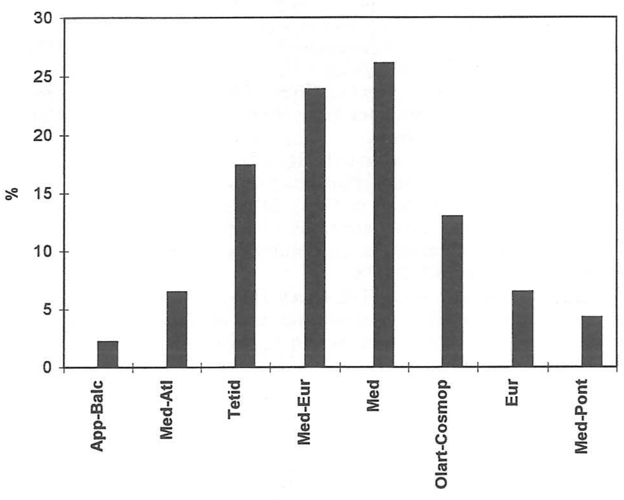

Fig. 4 - Simplified chorological spectrum showing the main chorological components of the flora.

This account illustrates the potential of the Bossoleto site as a natural laboratory. The key point is that it offers in a small area a wide plant diversity in terms of evolutive level (from procariota up to monocotyledons), taxonomic rank (from the ecotype up to the genus and above), ecological requirements and growth form. The presence of small but representative fragments of widespread vegetation types, such as xeric and humid grasslands, and mediterranean woodland, gives also the opportunity to work from the individual to the population and community levels. Epilithic moss vegetation with *Ceratodon, Pseudoscleropodium* and epiphytic lichen communities with *Usnea, Cladonia* etc., contribute substantially to the diversity within the dolin. No other CO_2-springs in central Italy is colonized by plant communities showing such a structural, ecological and taxonomic diversity (Miglietta *et al.*, 1993; Selvi, 1997). Recent physioecological studies on almost 30 species from this site have added substantial knowledge on different aspects of plant life under elevated carbon dioxide. In the long-term, these studies may help in improving our prediction capacity into the response of terrestrial vegetation under the expected global change.

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