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Plant Traits 2.0

State of the art and future perspectives for research
on plant functional traits in Italy



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Società Botanica Italiana - Gruppo di Lavoro per l'Ecologia
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Programma

Giovedì 9 febbraio 2017

- 9,30 – 10,00: Registrazione dei partecipanti, saluti di benvenuto
- 10,00 – 10,25: S. Pierce, B.E.L. Cerabolini - ***Plant traits: a decade of progress***
- 10,25 – 10,40: G. Astuti, D. Ciccarelli, F. Roma-Marzio, A. Trinco, L. Peruzzi - *Testing CSR theory: a single-species approach with Bellevalia webbiana as a case study*
- 10,40 – 10,55: L. Gratani, M.F. Crescente, R. Catoni, G. Puglielli, L. Varone - *Plasticity of plant and leaf traits in response to environmental factors*
- 10,55 – 11,10: R. Gentili, C. Montagnani, S. Citterio - *Ambrosia artemisiifolia traits in induced and natural interspecific competition*
- 11,10 – 11,25: R. Bolpagni, F. Spano - *Hydrophyte plant traits: plasticity and role of water and sediment quality*
- 11,25 – 11,45: Pausa caffè
- 11,45 – 12,10: C. Ricotta - ***Community ecology among plants and numbers: the role of functional traits***
- 12,10 – 12,25: E. Fantinato, S. Del Vecchio, G. Buffa - *The use of reproductive traits to analyze plant community stability*
- 12,25 – 12,40: E. Ladouceur, C. Bonomi, P. Iannetta, M. Tudela Isanta, A. Mondoni, P. Poschod et al. - *Contribution of plant and regeneration traits for detecting ecological differentiation across temperate alpine grasslands in specialist species*
- 12,40 – 12,55: M. Di Musciano, A. Stanisci, L. Frate, V. Di Cecco, L. Di Martino, A.R. Frattaroli - *The importance of dispersal traits in mountain environment to predict changes in plant species distribution under climate warming: the case study on central Apennines GLORIA summits*
- 12,55 – 14,00 Pausa pranzo
- 14,00 – 14,25: L. Conti & A. Acosta - ***Functional traits and community processes: origins and recent developments***
- 14,25 – 14,40: C. De Mollì, G. Brusa, B.E.L. Cerabolini - *Functional interpretation of plant communities via CSR*
- 14,40 – 14,55: E. Giarrizzo, S. Burrascano, T. Chiti, F. de Bello, J. Lepš, L. Zavatiero, C. Blasi - *Re-visiting historical semi-natural grasslands in the Apennines to assess patterns of changes in plant species composition and functional traits strategies*
- 14,55 – 15,20: G. Campetella - ***Forest vegetation changes and plant traits in different dynamic contexts: examples from Italy***
- 15,20 – 15,35: S. Chelli, E. Simonetti, C. Wellstein, G. Campetella, S. Carnicelli, A. Andretta, D. Giorgini, N. Puletti, R. Canullo - *Effects of climatic, soil, structural and management factors on plant functional traits in forest understory vegetation of Italy*
- 15,35 – 15,50: C. Wellstein, F. Spada - *Florogenetic origin explains forest resprouting capacity across topographical gradients in peninsular Italy*
- 15,50 – 16,05: M. Innangi, T. Danise; A. Fioretto - *Leaf traits of European beech along altitudinal gradients on the Italian Apennines: relationships with climate and litter stock*
- 16,05 – 16,25: Pausa caffè
- 16,25 – 16,40: V. De Micco, A. Balzano, E. Zalloni, G. Aronne, K. Čufar, P. Cherubini, G. Battipaglia - *Xylogenesis and functional wood traits in tree-ring series: past reconstruction, present assessment and future perspective*
- 16,40 – 16,55: A. Montagnoli, M. Terzaghi, G.S. Scippa, D. Chiatante - *Plant fine root traits in response to environment*
- 16,55 – 17,10: S. Bagella, R. Filigheddu, R. Benesperi, P. Giordani, L. Minuto, D. Viciani, G. Casazza - *Thorns, spines and prickles in the Italian flora*
- 17,10 – 17,25: E. Sgarbi, L. Olmi; C. Bignami - *Leaf traits: a micro-morphological characterization of grapevine (Vitis sp. pl.) genotypes*
- 17,25 – 17,40: C. Lambertini - *A phylogeographic perspective to understand functional traits in Phragmites australis populations*
- 17,40 – 18,00: Conclusione dei lavori

Venerdì 10 febbraio 2017

9,30 – 9,55: B.E.L. Cerabolini – *L'emporio dei traits e le prospettive di ricerca*

10,00 – 12,30: Testimonianze su esperienze pregresse di network a scala nazionale

Partecipano Giovanna Aronne per “La rete dei giardini fenologici” e Roberto Canullo per “La rete CONECOFOR”

A seguire tavola rotonda su potenziali attività del GdL di Ecologia, alla quale sono invitati a partecipare tutti i presenti

12, 30 Chiusura dei lavori

Plant Traits: a Decade of Progress

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In the decade since the last “**Plant Traits**” meeting hosted in Torino in July 2007, several aspects of plant primary functioning have been confirmed at the global scale. These include the observation that the leaf economics spectrum forms part of an overall “**plant economics spectrum**”, or a trade-off between investment of resources in perennial tissues or the early use of resources in reproduction. A secondary spectrum, the “**plant size spectrum**”, is heavily involved in plant competitive ability and has been confirmed to involve the integration of size-related traits at the level of seeds, organs and whole plants. Very recently this has been explained by the “**seed-phytomer-leaf theory**” of Hodgson, which relates meristem size in seeds and phytomers and their capacity to produce and support single organs. These major axes of plant functional variability work together to form the “**Global spectrum of plant form and function**”. This provides a framework in which plant primary functioning can be quantified and compared amongst species and individuals. It has also been recognized to represent major axes of variability predicted by theories such as Grime’s CSR (competitor, stress-tolerator, ruderal) adaptive strategy theory. Recently, common traits collected world-wide and representing the global spectrum have been used to produce a practical tool to allow adaptive strategy classification, in which plant life forms as diverse as aquatic herbs and tropical rainforest trees can be compared on an equal footing. This has been applied to investigate strategy variability across biomes world-wide and to compare plant communities along environmental gradients. We will present an up-to-date picture of the use of these tools as they are currently being used to investigate plant community properties and ecosystem processes world-wide. Based on current research activities, we suggest some possible directions for future work.

Testing CSR theory: a single-species approach with *Bellevalia webbiana* as a case study

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No sufficient attention was devoted so far to the evaluation of inter-population and inter-individual variability of tertiary CSR strategy (1, 2). As a case study, we selected five populations covering the whole range of the Webb's hyacinth (*Bellevalia webbiana*), a narrow Italian endemic (3).

In order to maximize the potential variation in functional (adaptive) traits among the populations, we took into account the following selection criteria: a) geographical cover of the whole species range, b) occurrence of different degrees and types of disturbance, c) occurrence of different types of soil, d) occurrence of an adequate number of individuals ($N > 50$).

Soil samples (500 g) were collected in three different points within the population extent of occurrence for each of the five sites, then mixed up and sent out for analysis to the *Centro di Ricerche Agro-Ambientali (CRA) "Enrico Avanzi"* (Università di Pisa) for standard analysis.

Functional traits were measured in agreement with the general criteria reported by (6). For 10 individuals per population the following parameters were measured in laboratory, immediately after the collection (March 2016): a) Leaf fresh weight (LFW, mg), after a night in refrigerator in deionized water; b) Leaf dry weight (LDW, mg), after 72 h at 70 °C in a stove; c) Leaf area (LA, mm²), measured after digitization of the leaf outline (600 dpi) by means of the software ImageJ v. 1.47 (7).

Subsequently, we put our data in the spreadsheet made available by (8), in order to automatically calculate the relative contribution (%) of C, S, and R parameters to the tertiary CSR strategy of each individual, obtaining a total of 50 triplets of data.

We aimed answering the following questions: 1) is the tertiary CSR strategy of this species still homogeneous at the species level, once inter-individual and inter-population variability is considered? 2) If not, is there a method to evaluate when it is appropriate to assign a single ternary set of values as representative of a species? According to our results, *B. webbiana* resulted as a 'CS' species, and this general picture did not change when considering either single individuals, populations or the "whole species" levels. However, our data suggest also an improper data merging when calculating mean values at the species level. In order not to miss this information, we advise that "deviant" populations should always be retained as additional points, in case some significant heterogeneity is found in comparing Coefficients of Variation (CVs). Hence, we advise to perform CSR analyses on more populations per species, and to verify if it is appropriate to merge the values in a single ternary set representing the "whole species". This can be easily achieved by means of simple CV comparison (putative "whole species" values should never show CV higher than single populations) and standard statistical tests, to identify which population(s) needs to be treated separately. Our results also attest for some degree of population-based plasticity in our case study, highlighting the potential interest of CSR theory also on studies aimed at characterizing functional traits at micro-evolutionary scale.

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Plasticity of plant and leaf traits in response to environmental factors

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Plants are exposed to heterogeneity in the environment where new stress factors (i.e. climate change, land use change and invasiveness) are introduced. In particular, climate change has been shown to affect abundance and distribution of plant species, as well as plant community composition (1). Nevertheless, adaptation to global change could require the evolution of a number of different traits that may be constrained by correlations between them (2). Thus, it is necessary to identify plant functional traits in which plasticity is likely to be a determinant in plant response to environmental factors change. Moreover, it is important to fully understand the ecological consequences at the ecosystem level considering that species with a greater adaptiveness may be more likely to survive in novel environmental conditions. Plasticity is recognized to be a major source of phenotypic variations since it influences natural selection and, consequently, patterns of diversification among populations and species (3). Nevertheless, the extent to which phenotypic plasticity may facilitate survival under changing environmental conditions still remains largely unknown. It is important to identify plant traits in which plasticity may play a determinant role in response to environmental changes as well as a full understanding of the ecological consequences at the ecosystem level (4). Leaf area index (LAI) is one of the most important variables of ecosystem structure for global researches, and it can be used as a basic descriptor of vegetation to establish the tolerance threshold to perturbations (5). Plants growing in stress conditions tend to have a conservative leaf morphological pattern to avoid the production of structures too expensive to be sustained (6). Moreover, morphological traits are linked to an enhanced plant capacity to grow in forest understories (7) by having an important role in resource acquisition (8). Among plant traits, specific leaf mass area (LMA) is at the center of a nexus of covering traits affecting the ecology of plant species (9-11). It is tightly associated with leaf life-span, both traits being pivotal in the carbon-fixation strategy (12). LMA variability is attributed to changes in both leaf thickness and density (13). Moreover, LMA is related to photosynthesis (14) which generally scales linearly with the leaf biomass investment per unit leaf area making the anatomy the main driver of the light-saturated rate of photosynthesis (13). In spite of a wide variability in both stomatal density and size there is a strong relationship between them independently by the plant groups (grasses and non-grasses) and for different stomatal distributions on either one or both leaf surfaces (15). Moreover, stomatal size and density determine the maximum leaf diffusive conductance to CO₂ and water vapor (14) and hence the photosynthetic capacity. Photosynthesis is the basis of carbon assimilation and ecosystem productivity. The ratio between leaf respiration to photosynthesis is indicative of the leaf carbon balance (13). Plasticity for physiological traits may allow plants to grow and reproduce in spatially or temporally variable environments (5). Morphological, anatomical and physiological traits may have a different role in plant adaptation to the variability of environmental factors.

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***Ambrosia artemisiifolia* traits in induced and natural interspecific competition**

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The genus *Ambrosia* (Asteraceae) is a worldwide emergency due both to strong allergic potential and to impacts on crop yields. Common ragweed (*Ambrosia artemisiifolia*), native to North America, is the most widespread *taxon* and consequently the most problematic one (1). *A. artemisiifolia* is a pioneer weed, able to dominate the early stages of vegetation succession in open/disturbed habitats (2). Assuming that a strong competition for habitat resources may inhibit the growth and fitness of common ragweed, we investigated if induced and natural dynamics of vegetation reduces the vigour of the target species. In a three-year field experiment (from 2013 to 2015), changes in competitive ability of *A. artemisiifolia* have been related to variation of meaningful vegetative and reproductive traits along the vegetation cover dynamism in a highly disturbed site. The experiment took place in an abandoned quarry area invaded by *A. artemisiifolia* (extractive basin of the Botticino limestone, Nuvolento, Lombardy, Italy) and three experimental sites (about 300 m²) topographically and environmentally homogeneous were selected. These sites were previously remodelled adding homogeneous topsoil. Three different treatments have been applied in each site as active (restoration actions with native hayseed and commercial seed mixture) and passive (spontaneous succession) vegetation recovery. Every year in spring and late summer, in three randomly distributed plots (3x3m) in each treatment of the three experimental sites, we surveyed vegetation parameters (estimated vegetation percentage cover, species composition and cover), abundance of *A. artemisiifolia* and the traits related to vegetative growth and reproduction: plant height (measured from the ground to the growing point of the main branch), lateral spread (measured as the maximum diameter of the plant), maximum leaf length (in one individual, measured from the petiole to the apex), maximum size of the spike (male inflorescence), total number of male inflorescences and seed weight. The survey showed that within three years both spontaneous and induced vegetation dynamics suppressed *A. artemisiifolia* in all sites, even with temporal differences, with a quite instantaneous decrease since the first year in stands with higher vegetation cover (3). The three-year monitoring of *A. artemisiifolia* abundance and traits during the vegetation succession demonstrated the reduction of the species fitness (decrease of trait values) when grassland cover increased, in accordance with previous works that found how the species is a weak competitor against dominant native gramineous and leguminous *taxa* (4, 5, 6). Measures to contrast or contain common ragweed contemplate mechanical (mowing), chemical (herbicides) and biological pest control methods, techniques often not fully sustainable for the environment, neither effective in any condition. This study, the first one in a ruderal and low-productive area, suggests a sustainable and habitat-ameliorative method to control and contrast common ragweed and it also highlights the usefulness of monitoring plant traits for finding and testing new solutions against alien plants in ecological restoration.

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Hydrophyte plant traits: plasticity and role of water and sediment quality

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Among vascular plants, hydrophytes (plant species adapted to aquatic life) have unique specificity in structural and eco-physiological terms (e.g., aerenchyma differentiation, active gas transport, carnivory). These adaptations ensure their survival and growth in aquatic ecosystems, which are critical habitats for plants. This is mainly due to the predominance of fermentative processes, which generate local phenomena of hypoxia/anoxia and favour the release of cytotoxic compounds, especially at the sediment level (1). The severe niche filtering effect exerted by aquatic ecosystems favours widely distributed chorological types (e.g., most of the aquatic taxa are cosmopolitan or sub-cosmopolitan), and very species-poor communities, often dominated by a single species. These specificities resulted in multiple and diverse morpho-functional traits, often used to develop interpretive and classification schemes (2). Diaz and colleagues (3), with the goal of identifying a global spectrum for plant species, have shown as hydrophytes are the range limits of some of the critical traits for the survival, growth and reproduction (four out of seven investigated: adult plant height, stem specific density, leaf area and leaf mass per area). At the same time, hydrophytes have been less investigated compared with the terrestrial species (4), and little or nothing is known about the role of water and sediment quality in driving the adaptive responses of hydrophytes, if not in terms of growth forms (5). Nonetheless, hydrophytes are widely used to assess the quality of the colonized systems, as well as to investigate their dynamic trajectories. They represent an excellent model system, useful to interpret the complex on-going global change processes, considering the intrinsic high vulnerability of aquatic ecosystems. We intend, therefore, to expand the available information on the main morphological and functional traits of hydrophytes and to evaluate the local effects of water and sediment quality on their plasticity.

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Community ecology among plants and numbers: the role of functional traits

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The use of functional traits in community ecology is increasingly common and has broadened our understanding of the general mechanisms that regulate the diversity of species assemblages and their relationship with ecosystem processes. The resulting development of functional approaches has led to a proliferation of different methods, which hamper the generalization of existing results. Therefore, there are many open methodological questions about these methods and the related metrics for summarizing community functioning, such as which traits to use, how to code them, and how to combine them.

Here, I show that for quantifying relevant aspects of community organization in the most appropriate manner, the selection, application and interpretation of functional metrics should be logically connected to the research question. I conclude with a short discussion of selected directions for future research that may lead to a better understanding of community organization and functioning.

The use of reproductive traits to analyze plant community stability

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Plant traits involved in processes pertaining sexual reproduction can represent a viable tool for analyzing the stability of plant communities. Sexual reproduction in angiosperms has three sequential stages: pollination, fertilization and seed maturation. Pollination is the first step in the sexual reproduction of plants, and can be relied on abiotic vectors or on animals. The number of angiosperms pollinated by animals is relevant, for an estimated global average of 85% (1). The majority of animals visit flowers for food, feeding on sugary nectar and/or on the pollen itself, thereby passively picking up pollen and carrying it to another flower. Pollination by animals is an ubiquitous ecological interaction which likely has a marked influence in ecological community dynamics and diversity thereby playing a crucial role in maintaining ecosystems' integrity. Recent research has evidenced several plant traits and structural attributes of pollination interactions that are associated with plant community stability, resistance to secondary extinctions following species loss, and the consequent provision of a vital pollination service (2). To date most studies have evaluated pollination interactions under the assumption that all partners coexist in the same time. However, a temporal analysis may give a misleading picture. In the light of these considerations we examined the stability of dry grassland communities by analyzing temporal changes of some plant reproductive traits as well as of visiting insects – i.e., the degree of generalization of plant species, of pollinator guilds and of the overall pollination network, nectar and pollen production, and pollinator feeding preferences. In fact, in temperate dry grasslands (3), plants and flower visitors are active during periods varying from several days to several weeks, possibly leading to temporal changes in the structure of the pollination network and thus to its resilience.

We monitored contacts between plant species and pollinator guilds every 15 days during the overall flowering season (11 monitoring surveys). For each plant species we measured nectar volume by using microcapillary tubes and counted the pollen grains number on five flowers. For each monitoring survey we built a quantitative plant-pollinator interaction matrix and we calculated the mean value of pollination generalization of plants and pollinator guilds, as well as of the overall network. A high network specialization entails a high dependence of plant diversity to flower visitor diversity (and vice versa), thereby resulting in less resilience to perturbations. Furthermore, for each monitoring we calculated the ratio between the total number of pollen grains and the total volume of nectar, weighted for flowers abundance, and we analyzed the relative abundance of pollinators grouped according to their foraging preferences (i.e., pollen-feeding, nectar-feeding and both pollen and nectar-feeding).

Lowest degrees of generalization of plant species were found during late spring – early summer, when pollinator guilds showed the highest degrees of generalization, while plant species degree of generalization reached the highest values during early spring and late summer, when both generalist and specialist guilds of pollinators were observed, resulting in an asymmetric structure of interactions. While the asymmetric structure was maintained through the flowering season, the degree of generalization of the pollination network was not constant and followed a negative trend. Temporal trend of floral resources highlighted that nectar was associated with plant specialization and pollen with generalization. Thus, nectar availability was higher during late spring – early summer, while pollen prevailed during early spring and late summer. Insects feeding of both pollen and nectar showed a steady trend through the community flowering season, while pollen-feeding and nectar-feeding insects showed two opposite patterns: pollen-feeding insects prevailed during early spring, while nectar-feeding insects during late summer. Although the presence of an asymmetric pattern may enhance the overall ecosystem resilience over time and prevent secondary extinctions, the temporal trend of the pollination network degree of generalization highlighted some critical moments: during late summer the scarcity of nectar may force insect food choice towards nectariferous plant species, thus limiting pollinator sharing and the overall network redundancy and resilience. Plant reproductive traits may represent a powerful tool for detecting interspecific interactions in plant community, enabling, for example, the identification of threatened interactions to which focus conservation efforts.

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Contribution of plant and regeneration traits for detecting ecological differentiation across temperate grasslands using specialist species

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While trait differences are often investigated between broad functional types, traits related to abiotic and biotic conditions of habitats functionally similar but ecologically distinct are more subtle to detect. We test whether differences in functional traits exist in five widespread alpine grassland types in temperate Europe. We expect that separating species that distinctly, and significantly occur in one habitat over any other (specialists), from those that occur across many habitats (generalists), will indicate subtle niche differences in trait-based approaches. We identified 416 specialist and 273 generalist species across habitats at the continental scale. We compiled trait data related to adult plant traits, seed germination and regeneration traits. There is a different nature of the principal mechanisms behind community assembly (environmental and biological), and regenerative traits depend on both of these, so they may be particularly effective for identifying these strategies in both broad-scale biogeographic patterns and in local scale gradients. In the trait multidimensional space computed with a Principal Component Analysis, the trait spectrum of all 689 species demonstrates the set of specialists for each habitat type showed maximum differentiation between low-altitude and high-altitude habitats. The role of regeneration and seed germination traits is significant in showing differentiation between low and high altitude habitats, sometimes with differentiation of mid-altitude habitats as well. Overall, this study demonstrates how separating specialist species across habitats, and combining structural and regeneration traits can provide a more complete picture of functional composition for natural grasslands.

The importance of dispersal traits in mountain environment to predict changes in plant species distribution under climate warming: the case study on central Apennines GLORIA summits

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The global climate is rapidly warming and the causes are rooted in human activity. Greenhouse gases and aerosols emissions are the main causes of global warming and variations in natural cycles (1). Thus, in recent years, a scientific interest in understanding how climate change affects the biotic communities arose. Actually, high mountains can be considered particularly appropriate environments to detect the effects of climate change on natural biocenoses at a global scale (2).

As already demonstrated in several studies, many species in mountains have shifted their upper distribution limit upslope in recent decades, resulting an increase in species richness at high elevations, at least in temperate bioma (3). Simultaneously with the upward shift of species, a decline in cold-adapted species is expected (4) but it has only rarely been observed to date. The ability of plants to respond to warmer conditions (i.e. colonizing new areas) depends on both the dispersal capacity of a species and the local ecological conditions, which act as filters on plant establishment, selecting for those species with traits suitable for the site's local conditions (5). In the context of climate change, the identification of the plant traits of newly appearing or disappearing species helps us to understand the ongoing selection processes, which are important for predicting future species assemblages (6). In this framework the effects of altitude and aspect on the vascular plant species composition, dispersal traits (pollen vector, diaspore morphology, dispersal of diaspores, fruit type), plant community structure (life forms) and ecology (Landolt ecological indicators) have been investigated.

We performed this study using the plant species cover data collected in 140 permanent plots of 1m² in 2015 in three different GLORIA project (7) summits in Majella National Park, along a vertical (elevation) and horizontal (different directions) gradients. This synchronic approach was performed according to space for time concept, demonstrated that in mountain ecosystem, environmental gradients (space) can be utilised as predict of global change gradients (time) (8). Species composition was analysed performing a cluster analysis, followed by the analysis of similarities between different summits and aspects through the ANOSIM test. Then to investigate the distribution of traits along the two gradients we performed the four corner analysis using R. Moreover, for the most relevant species the morphometric traits of seeds were collected. The results highlighted a significant change in plant traits composition along the altitudinal gradient, especially for diaspore morphology considered the most important trait that affects the plant species capacity to cover long distance and colonize new habitats. In addition, a checklist of rampant plant species was identified. These results may help to have a better view on the distribution of dispersal traits in Mediterranean mountain ecosystem and to find out the most successful traits that influence the colonization capacity of new habitats. For the future studies we planned to increase our plant traits database and to strengthen the monitoring network in Central Apennine to understand the real dispersal capacity of species through in situ seeds trapping. We aim to collect seeds dispersed by wind along the altitudinal gradient and to identify which plant species could be considered the most potentially invaders under climate change.

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Functional traits and community processes: origins and recent developments

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Functional traits have been increasingly used to describe several ecological processes. By capturing essential aspects of species' ecophysiology, morphology and life-history strategy, functional traits offer a mechanistic link between fundamental biological processes and community dynamics. In this presentation we aim to recall the origins of our trait-based approach in the early nineties and highlight how it has been developed in more recent years. The first studies that analyzed plant communities using morphological characters were performed in Argentina's grasslands and enabled us to detect plant morphological shifts at increasing levels of disturbance (1).

In the last years, we have mainly focused on functional traits as a useful tool to understand community-level invasion processes and impact. Although we have found some differences in the morphological and physiological characteristics between alien and native species (2), to date no universal set of attributes that could explain invasion success has been recognized. However, we know that invasion success is highly dependent on the interaction between the invasive and the native community's abiotic and biotic characteristics (3). Since biotic resistance and the resulting invasion success are mainly based on the competitive interactions between alien and native species, an important part of the trait-based research on invasion success mechanisms has focused on finding functional patterns linked to limiting similarity (4). Further, by analyzing the impact on not only the communities' taxonomical diversity but also their functional diversity we have been able to reveal an unexpected ecological cost of plant invasions (5). Most recently, functional community ecology has been questioned for often excluding plastic or evolutionary community dynamics. Although trait plasticity is often thought to be a key element in biological invasions (6), most community invasion studies still use average species-level trait values to assess ecological similarities (e.g. 7). However, considering intraspecific trait variability can help clarify the link between trait similarity and coexistence mechanisms. We will present two case studies addressing this particular issue for invasion success and invasion impact. First, an experimental study showing that the interplay between changing environmental conditions and plastic trait responses of alien species can weaken biotic resistance and lead to invasion success of already competitive species. Second, a study of the impact of a highly invasive species (*Carpobrotus* spp.) on native communities' functional diversity in coastal sand dunes, particularly by considering native species plastic trait responses to competitive pressure by the invader.

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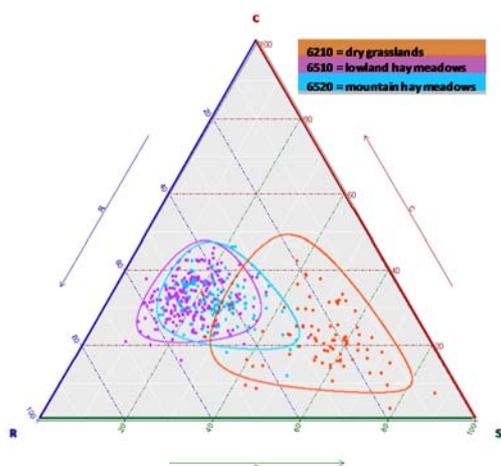
Functional interpretation of plant communities via CSR strategies

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The use of functional traits allowed to combine plant species in functional groups, not taxonomic coherent groups. In this way, the basis for a valid approach for studying a wide range of plant communities were provided since the eighties (1, 2). By focusing on Plant Functional Types or Plant Strategies, rather than on individual species, it is possible to look in a functional way at general processes by which abiotic factors and plant species interact in the establishment of plant communities in a particular habitat (3, 4). A Plant Strategy scheme was developed by Grime (5, 6) with the CSR theory which investigates in a triangular space, set of plant traits owned by species in certain habitats or in response to ecological processes. Recently, an improved method to calculate coordinates of species in the CSR ecological space, has been made available (7) and validated for a range of plant species across biomes worldwide. Although CSR plant strategies were already used in ecological analyses, what is now missing is a standardized method to represent plant communities. For this reason, we developed a procedure that, starting from CSR ternary coordinates of individual species of a plant community, defines the position of the same plant community in the CSR space.

The CSR triplets of each species were calculated using the spreadsheet StrateFy (7) starting from three simple traits: leaf area, leaf fresh weight and leaf dry weight. The cover-abundance indexes of species in a relevé were transformed in percentage accounting the median value in each rank of cover-abundance. As the dominant species are main drivers of plant communities (8), the CSR triplets of each relevé were calculated as a community weighted mean (CWM) using species median values as weight. CSR triplets are compositional data (9), so they were analyzed and shown through some packages in the software R. CSR triplets of relevés were plotted in a ternary diagram (the CSR space) in which mean and 95%-probability region of population were also shown. Statistical tests was performed to assess differences among plant communities along the three axes.



Our first analyses focused on different plant communities, including those under Habitat EC Directive. We analyzed hay meadows and dry grasslands (EC habitats 6210, 6510 and 6520 - Fig. 1), *Carex curvula* and *C. firma* alpine grasslands (habitats 6150 and 6170) and fir or spruce conifer forests (habitat 9410). We also investigated ecological succession involving lowland heathlands. The procedure we defined looks suitable and convincing in comparing plant communities, allowing functional analysis of vegetation processes.

Fig. 1 Ternary diagram of the CSR space for three meadow plant communities: points represent relevés, lines their 95%-probability region of population.

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Re-visiting historical semi-natural grasslands in the Apennines to assess patterns of changes in plant species composition and functional traits

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European semi-natural grasslands are among the most species-rich ecosystems in the world (1) but modification in their management could lead to dramatic changes in their structure and species composition. They are extremely vulnerable to land-use changes and, for their conservation, it is crucial to understand the vegetation dynamics that occur in these systems, especially those following both abandonment and intensification of agricultural practices.

Our study focused on multi-temporal data of *Bromus erectus* communities collected across seven study sites along the Apennines (Italy). We explored shifts in vascular plant species composition and functional traits addressing the following questions: i) which are the main directions of change occurred during the past five decades? ii) Which environmental, management, and landscape factors have influenced these changes?

In 2013-2014, we used a stratified random sampling design to revisit 132 historical plots originally sampled between 1966 and 1992 and associated with detailed vegetation maps. We integrated vegetation data with plant life forms and quantitative functional traits chosen according to the leaf–height–seed scheme (2). Plots were divided in 17 groups based on study area and original community type. We compared each new plot with the quantitative species pool of the corresponding historical group; species composition changes were calculated using Bray-Curtis coefficient, and shifts in functional traits were quantified as differences in community weighted means. These measures of change were used as response variables in mixed effects models including climate, topography, management and landscape metrics as explanatory variables. We also identified the species that increased or decreased in abundance through a redundancy analysis.

The greatest changes were related to successional dynamics, which occurred mainly in grasslands developing at low altitude and in flattest sites where the soil organic horizon was relatively thick. Colonization by shrubs and trees was facilitated by high soil pH and amount of adjacent forests. Also management factors affected the patterns of shifts in species composition and functional traits: grazing intensity was negatively related to the degree of compositional change as well as to the abundance of woody species, whereas the increase of species associated with frequent grazing disturbance was found at sites with higher values of soil salinity.

Our conclusion is that Apennine semi-natural grasslands have undergone substantial changes in species composition and functional traits during recent decades. These changes mainly indicate successional dynamics likely following a decrease in grazing intensity, whereas some more accessible grasslands have experienced an increase in disturbance-tolerant species. The combination of the re-visitation approach with functional traits allowed to clarify different directions of changes in species composition adding information on the ecological processes related to these changes.

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Forest vegetation changes and plant traits in different dynamic contexts: examples from Italy

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In a context of noticeable climate and land use changes, where ecological responses are already clearly visible, a lot of studies tried to elucidate the mechanisms supporting observed patterns of biodiversity and their environmental drivers. In this respect, Magurran (1) emphasized that temporal changes are essential for accurate diversity measurement and assessment and, more importantly, to improve understanding of the processes that underpin community structure and functions. The taxonomic approach for the study of the understory dynamics in forests has been recently linked to the functional trait approach. Plant functional traits (PFTs) demonstrated to be a very effective tool in understanding the crucial mechanisms shaping the species patterns within ecosystems (2, 3). Here I present a series of results obtained focusing on community-level patterns in plant traits of the vegetation of beech forest understory in Italy, using two different approaches: i) beech coppices chronosequence - sampling and re-sampling in a series of coppiced beech forests in various stages of recovery after the last coppicing event; ii) long term diachronic observations in permanent monitoring plots placed in old growth beech forests, located along a latitudinal and climatic gradient. Questions addressed to the chronosequence datasets were related to 1) mechanisms of species pool maintenance, changes in species number, composition and functional groups, 2) identification of relationships between abiotic conditions and the plant functional traits responding to forest changes along a chronosequence; 3) mechanisms of species turnover (colonization and extinction) in the mosaic of regenerative phases produced by coppicing. Questions addressed to the long term datasets collected in old growth beech forests were related to identify responses in vegetation changes and plant traits favouring species persistence in relation to different environmental conditions. In the coppice system, our results underline the importance of landscape heterogeneity in conditioning plot-scale species compositional changes: the “shifting mosaic” consisting of differently aged forest patches, together with a relevant geomorphological variability, seem to be the key factors in determining local ecological processes (4). We found no significant change in the proportion of clonal species along the studied chronosequence. In contrast, most of the traits and about the half of the clonal growth organs showed correlation with stand age or preference for a certain habitat (i.e., stage of regeneration). Clonal and bud bank traits proved to play an important role in the persistence of species subjected to forest coppicing cycles in the studied area (5). Abandonment of coppicing leads to decrease of species diversity but at the same time to a selection of species with larger SLA, more frequent multiplication and short-distance seed dispersal ability—all of which are traits and syndromes related to beech forest species specialists (6, 7). In the old-growth forest, different plant traits drive species persistence according to the local context: seed mass seems to be relevant in driving fine-scale species persistence mainly in the northernmost stands with relatively stable climatic conditions, while clonal traits play key role in stands characterized by summer droughts. Leaf traits are important in driving species persistence along the whole gradient, but with opposite attributes between northern and southern stands. The relatively constant beech flora over large biogeographic distances (similar species composition and trait pool in the selected permanent plots) gave remarkable variation in responses. This results are particularly relevant in changing climatic conditions facing with increasing uncertainty and increasing extremities. Traits evolved to steady state competitive environments (mesic dark forest) might be less important in the future and then replaced by other traits (of the same species) better responding to stresses and disturbances.

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Effects of climatic, soil, structural and management factors on plant functional traits in forest understory vegetation of Italy

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Understanding how vegetation responds to environmental variations is a fundamental goal in ecology, and the trait-based approach seems to be particularly suitable, since functional traits mediate the response of plants to environment (1). In this context, several studies demonstrated the relationship between plant functional traits (PFTs) and individual environmental drivers such as climate, disturbance regimes or land-use change across different scales (2, 3, 4, 5). However, the observed pattern of vegetation functional signatures cannot be attributed to a single explanation, but rather to a combination of environmental factors (6, 7). Unfortunately, only a small number of studies showed how PFTs may be influenced simultaneously by different environmental variables and explained the relative role of different drivers (8). Furthermore, such studies have been mostly conducted in non-forest ecosystems.

We aim to quantify the relative contributions of 17 climatic, soil, structural and management factors in determining the community-level PFT values of the forest understory vegetation of Italy. The ICP-Forests Level I dataset has been used, where vascular species have been recorded within 201 sample areas (stands) using a probabilistic approach (thus, representing the Italian forests). Three PFTs have been selected being fundamental trade-offs controlling plant strategies: *specific leaf area (SLA)*, *canopy height* and *seed mass* (9). Prior to the analysis, a stepwise ordination has been used to select factors with higher explanatory power. Then, a variance partitioning has been applied in order to assess the contribution of climate, management, soil and structural factors (alone and in combination) to explain the variation in attributes. Finally a Redundancy analysis has been used to evaluate the relation between PFTs and factors.

For *canopy height*, climatic factors (mean temperature and rainfall/PET, i.e. aridity index) are responsible for 25% of the variation in understory community PFT values. However, also soil (pH, available K, effective soil volume) and structural factors (forest type, n. of tree layers) play a relevant role (13-14% of the variation). While *SLA* variation is explained mainly by management factors (9%, intensity of management) and *seed mass* mainly by soil factors (17%, pH) and secondly by climatic factors (12%, potential evapotranspiration). However, unexplained variation is very high for all three PFTs, suggesting that many other biotic and abiotic factors play a key role.

In detail, warmer and drier stands (within Mediterranean forest types) seem to be associated to higher values of *canopy height* and *seed mass*, respectively; stands with lower management intensity lead to higher values of *SLA*; stands with higher level of pH are associated to higher values of *seed mass*, while stands with deeper soils and more available K are associated to higher *canopy height*.

Our results could be useful to explore the effects of climate and land-use changes on the functional signature of forest understory communities.

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Florogenetic origin explains forest resprouting capacity across topographical gradients in peninsular Italy

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Resprouting in tree species plays a crucial role for their survival under conditions of natural disturbance and human impact (1, 2, 3). Here, we assess for species rich late successional forests across altitudinal gradients on the western side of the Apenninic chain in central Italy (4) the degree of their resprouting capacity. We combined species composition from twenty 400-m² forest plots with information on resprouting capacity for 43 tree species. We analyzed the relationships between resprouting capacity and topographic and climatic variables (5). The results are based on NMDS ordination, linear models and ANOVA. Based on diverse and relatively chaotic disturbance regimes across the landscapes we expected irregular patterns of resprouting capacity. However, surprisingly, we found clear gradients in this functional trait across the forests. Resprouting capacity of forest stands decreased with increasing altitude from the Tyrrhenian coast to higher elevations. It emerged that resprouting capacity significantly differed between groups of distinct florogenetic origin (6). Evergreen laurophyllous and sclerophyllous species (paleotropical geoflora) had significantly higher resprouting capacities than deciduous mesophytic species (arctotertiary geoflora). The distribution of these florogenetic stocks along the altitudinal gradient shows a concentration of the evergreen species at lower altitudes while deciduous species are restricted to higher altitudes. The pattern of resprouting capacity of forest stands along altitudinal transects of the central Italian Apenninic chain are most likely the legacy of biogeographical historical processes and residuality. Our findings on the landscape-level patterns of forest resprouting capacity have important implications for evaluating the vulnerability towards future climatic and land-use changes.

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Leaf traits of European Beech along altitudinal gradients on the Italian Apennines: relationships with climate and litter stock

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Climate change is forecasted to alter both forest species distributions and organic carbon cycle, particularly in the Mediterranean region (1). One of the forest species that is most threatened by climate change is the European Beech *Fagus sylvatica* L., which grows in Italy, between altitudes of 800 and 1800 m along the Apennines (2), covering 9.4% of the country's total forest area (3). A forecast for climate change scenarios showed that, in the Apennines, Beech could climb up on mountains from its current median elevation of 1200 m to 1500-1700 m having strong impact on carbon stock (1). Carbon accumulation in the soil is strictly related on leaf litter input and litter stock that are, ultimately, dependent on both leaf chemical composition and shape (4). Thus, we investigated leaf traits of green leaves and litter stock on the forest floor in 6 Apennines Beech stands along altitudinal gradients in order to a) determine the relationships between leaf traits and climate variables, b) evaluate the relationship between litter stock and leaf traits. We used both a classic and geometric morphometric approach to study leaf traits to account for changes in size as well as shape (5). Our results showed that Beech leaves are strongly affected by climate variables such as annual precipitation (for size variables) and temperature seasonality (for shape variables), and that these trends are reflected in the accumulation of litter stock.

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Xylogenesis and functional wood traits in tree-ring series: past reconstruction, present assessment and future perspective

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On-going climate changes are expected to influence wood production in trees, thus leading to changes in the productivity of forests. In the Mediterranean region, the increasing risk for drought stress and extreme events (such as heat waves) will likely determine a decrease in wood formation with negative consequences on the productivity of Mediterranean forests and related ecosystem services, such as carbon fixation in long-lasting wood pools.

Given the growing interest in implementing wood research to evaluate the health status of forests, wood anatomy has renewed its methods and approaches as a discipline more pointed towards a trait-based ecology. Several definitions of traits, including wood traits, have been formulated and recently wood anatomical traits have been revisited in the light of the importance that wood functionality has on tree performance and forest dynamics (1, 2). The process of integration between wood anatomy and dendroecology has also raised interest in considering “anomalies” in growth ring patterns as important functional traits to infer intra-seasonal ecological information from tree-ring series. Many dendrochronological studies aim at developing mean tree-ring width chronologies through the principle of cross dating which focuses on phenomena at the population level. Thus, in the traditional dendrochronology, “anomalies” in growth rings are considered a constrain in the development of chronologies and are likely avoided. In the context of trait-based ecology, difficultly-crossdatable tree-ring series are even more interesting because they contain valuable ecological information at a finer scale. In Mediterranean woods, such “anomalies” are more the rule than the exception and are referred to as intra-annual density fluctuations (IADFs) in tree rings (3, 4). IADFs are defined as structural anomalies caused by deviations from the “normal course” of xylogenesis during the growing season, in which the “normal conditions” happen when cambial activity stops once a year. Mediterranean woods show peculiar patterns of cambial activity, stopping more than once a year, leading to the formation of frequent and different types of IADFs in response to intra-annual variations in temperature and water availability.

Here, we report some study cases in which the ecological meaning of functional wood traits linked to hydraulics and mechanics has been analysed in tree-ring series of Mediterranean shrub and tree species. We also report information on xylogenesis to highlight the periods of IADF formation and identify the environmental factors triggering them. Moreover, relations between anatomical parameters and intrinsic water use efficiency (WUE_i), calculated using carbon stable isotopes, are analysed. All data are also linked with climate.

Results highlighted that the responses of Mediterranean woods to environmental factors are species-specific. Moreover, this multidisciplinary approach, combining dendroecology, functional wood anatomy and eco-physiology, results to be useful to reconstruct the past behaviour of the plants in response to climate (through the analysis of functional wood traits and isotopes in long tree-ring series) and to follow “real-time” wood formation in response to environmental drivers (through the analysis of xylogenesis), thus gaining information to model future responses of wood production and species adaptation in changing environments.

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Plant fine root traits in response to environment

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Coarse, small and fine roots compose the plant root system. Bigger roots mainly provide stability to the plant through the function of anchorage to the soil. Thinner fine roots ($d < 2\text{mm}$) provide water and resource acquisition and in general an interactive exchange with the surrounding environment. Fine roots are ephemeral and have a highly variable and short lifetime, spanning from few days to few months. Changes in fine root dynamics are fundamental for plants to face environmental constraints such as water shortage and high temperature. Indeed, in many cases, plant cost-benefit analysis leads to a destination of resources to build up a more extensive fine root system (longitudinal growth) mainly composed of very fine roots ($d < 0.5\text{mm}$). This type of resource allocation would result in a significant increase of the soil exploited as well as of the specific root length (SRL). On the other hand, in the presence of enough soil water content and resources, plants may invest in the radial growth type enlarging the fine root diameter and therefore enhancing the water and nutrient transport function. Deepening the knowledge on fine root traits such as biomass, length, diameter size distribution and SRL is of fundamental importance for a better understanding of strategies used by plants to cope with highly diverse and fast changing environmental conditions. The aim of the present work is to review the last studies concerning fine root dynamics and morphology in response to environmental stimuli. These studies were carried in: 1) oak and beech natural forest at different latitudes in Italy (1, 2); 2) young oak seedlings undergone to mimicked drought and fire in controlled conditions (3, 4); 3) agronomic plants subject to biochar soil amendment (5). A better comprehension of the fine root characteristics for different species, age and growth conditions could contribute to build up a solid ground for the next future research in the field of plant functional traits.

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Thorns, spines and prickles in the Italian flora

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Thorns, prickles and spines are sharp appendices of different origins whose presence in the Mediterranean floras has an ecological, evolutionary and biological meaning. Nevertheless, little information is available on the number and on the characteristics of the spinescent plants at local and regional scale. The aims of our research were: i) to create a check-list of spiny, thorny and prickly plants belonging to the wild flora of Italy and ii) to characterize this group basing on different morphological traits and ecological features.

The check-list, based on the analysis of the flora of Italy (1, 2), includes 404 taxa belonging to 31 families, Asteraceae (44%), Rosaceae (19%) and Fabaceae (12%) being the most represented ones. Each taxon was associated to one or more of the following types of spinescence: thorns, prickles, spines (leaves fully converted to spines, spinose or pungent apical process, laminar spines, stipular spines, petiolar spines, leaflet spines, laminar spines). Moreover, the following attributes were: biological form, thermoclimate (termotypes *sensu* Rivas-Martinez) and habitat type (Corine Biotopes Level 1). Some 50% of the plants present just one type of spinescence. The more common types were some of those derived from leaves (i.e., spinose leaf margins 26%, leaflet spines 19%, apical processes 19%) followed by prickles (17%) and thorns. Hemicriptophytes (42%) and Phanerophytes (33%) were the dominant biological forms. The distribution between Mediterranean and Temperate thermoclimatic belt was balanced (52% vs 48%) with some 70% of the species occurring at least in two or three different thermoclimatic belts. The richest habitat in spinescent species were grasslands (28%), ruderal areas (21%) and woods (17%).

We conducted a Principal Component Analysis (PCA) on type of spinescences to evaluate the correlations between them. Furthermore, in order to elucidate whether the habitat and thermoclimate may influence the spinescence composition a Redundancy Analysis (RDA) was used. The “envfit” function in “vegan” was used to determine the possible relationships between the spines composition vs. habitat and thermoclimate. To test the probability that type of spinescences would co-occur we used the approach implemented by Veech (3).

PCA showed spinose apical process, leaflet spines, spinose leaf margin, thorns and prickles as the most effective traits in discriminating between species. In particular, the presence of spinose apical processes and leaflet spines characterized herbaceous species, whereas the presences of thorns and prickles were strictly associated with tree and shrub species. RDA detected significant correlations ($p < 0.05$) with the spinescences composition vs. three habitats and vs. four out of seven termotypes. Mediterranean thermoclimate was associated with thorny species, whereas temperate thermoclimate was correlated with species with prickles or spinose leaf margin. Species bearing prickles and spinose leaf margin species with spinose apical processes preferentially occurred in anthropic habitats and a weak correlation between bracts and forest habitats was also observed. Notably, the presence of thorns excluded the presence of the majority of other type of spines.

The relationship between spinescences and both ecological feature and taxonomy supports the hypothesis of interactive processes of both selective pressures and phylogenetic constraints in the evolution of spinescences in the Italian flora.

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Leaf traits: a micro-morphological characterization of grapevine (*Vitis* sp. pl.) genotypes

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The analysis of leaf structure provides important elements to ecological studies and useful information to evaluate the susceptibility or tolerance to biotic and abiotic stress. A number of histological studies have been carried out on grapevine cultivars, relating leaf traits to resistance against fungal pathogens (1), water stress response (2) and other environmental conditions (3). In the present work the leaves of 17 different grapevine genotypes, *Vitis Berlandieri*, *Vitis vinifera* ssp. *sylvestris* and cultivars of *Vitis vinifera* ssp. *sativa* from six different Italian Regions, have been observed at the Scanning Electron Microscope (SEM). The leaves of all genotypes showed stomata only on the abaxial surface and scattered in the epidermis, but with a great variability, in terms of stomatal density and size, occurring among species and cultivars: mean stomata density in fact ranged between 100 and 200 stomata/mm². High values of stomata density (more of 200 stomata/mm²) were recorded in Nero d'Avola and *V. Berlandieri*. The lowest values occurred in wild grapevine and in Sangiovese but, concerning the size of stomata, these last genotypes showed significantly larger and wider stomata when compared to the others. Stomata density appears to be a very variable parameter, related to genotype (4), but also to many environmental conditions, i.e. water stress and light irradiance (5) and CO₂ concentration (6). Furthermore, raised and sunken stomata were visible in the same leaf with different ratios. In *Vitis Berlandieri* more than 99% of the stomata was protruding from the surface of the epidermis while Nero d'Avola exhibited about 89% of sunken stomata. Density, position and types of trichomes differently characterized the leaves of studied *Vitis* accessions; prostrate and erect hairs were mainly observed on abaxial side but in some genotypes they were observed also on upper epidermis. Leaf hairs are morphological characters that are taken in consideration as ampelographic descriptors of *Vitis* species and cultivars but they play also an important role in pathogen resistance (7). In this study the analysis of leaf traits allowed to obtain a micro-morphological characterization of grapevine genotypes; some characters may be related with plant resistance to stress.

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A phylogeographic perspective to understand functional traits in *Phragmites australis* populations

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The common reed *Phragmites australis*, is a cosmopolitan polyploid species which tends to dominate wetland vegetation all over the world. It is absent only in the polar regions of both hemispheres. Despite its adaptations to wetland hypoxic soils, this plant can establish in very diverse habitats, tolerate drought, salinity, disturbance and can rapidly spread as an invasive species. *P. australis* is regarded as a plant with high phenotypic plasticity and wide ecological amplitude, however these traits have a genetic basis and are often the result of adaptations evolved independently in different ranges.

The Mississippi River Delta is a hot spot of diversity for *P. australis*. Here strikingly different morphologic and ecophysiological phenotypes grow next to each other in the same habitat. This phenotypic variation cannot be explained by local selection, sharing the genotypes the same environment, but by multiple recent introductions from different parts of the world. The genetic pattern of the European populations of *P. australis* shows that the European populations were likely similar to the population in the Gulf Coast at some point in time, but gene flow and introgression have smoothed genetic, morphologic and eco-physiological differences among genotypes of different origin. Although *P. australis* is a clonal species, seeds are the main form of reproduction. Pollen and seeds are dispersed by wind and birds, and can travel long distances before deposition and establishment. The use of *P. australis* as a resource (thatching, paper, wetlands restoration, constructed wetlands and bioenergy crops) has further facilitated dispersal over long distances in Europe and world-wide. As a consequence, *P. australis* populations can include very distantly related genotypes originating in other parts of world and thus be very diverse genetically, morphologically and ecophysiologicaly. Being one single species, differences among genotypes within populations are often attributed to the normal intraspecific variation, however such differences can be extreme and due to phylogeographic diversity. Long-distance dispersal is an important and underestimated source of genetically-determined diversity in *P. australis* populations. This variation should be taken into account in studies exploring functional traits of *P. australis* dominated communities, as the response can be different for each sampled genotype and independent from the current environmental conditions of the habitat in which the population is sampled.



Mississippi River Delta. Patches of different colour are *P. australis* genotypes of different phylogeographic origin and have different morphology and photosynthetic traits

Exploring ecological hypotheses by examining relations among plant traits and environmental predictors: the application of phylogenetic comparative methods

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The associations between plant traits and environmental conditions can provide deep insights into evolutionary processes. Hence, by comparing species living in different niches, botanists traditionally sought for systematic differences in plant traits to assess their functional needs in the environment. In this context, statistically significant correlations were usually interpreted as evidence for the adaptive significance of a presumptive functional trait. With respect to phenotypic variation and functional evolution, however, it is crucial to evaluate whether correlations between species traits or between a trait and environmental parameters reflect patterns of evolutionary convergence or may be due to common heritage from their ancestor (1).

Hypotheses about the adaptive significance of a trait have been often tested by making comparisons among species. However, because of shared evolutionary history, species do not provide independent data points (2). Analyses not accounting for the degree to which species are related can lead to situations in which relationships within groups are masked by phylogenetic differences between groups or where apparently relationships are supported by few truly independent events. Several methods, depending on the data type and structure, have been developed for analysing comparative data while taking phylogeny into account (3). In addition, complete phylogenies with estimated branch lengths have become widely available (4) and thus, the application of phylogenetic comparative approaches in plant science should be enhanced (5).

In this context, the large amount of data collected by plant ecologists and the use of phylogenetic comparative methods allow to explore macroevolutionary patterns, supporting adaptive interpretation of functional traits but also profitable to assess their phylogenetic inertia (6). Furthermore, ecological studies are often conducted at the population level and involve several individual measurements. While the former allows to get insight into microevolutionary patterns, the latter guarantees the availability of within-species variation measurements. Within-species variation should not be regarded as a confounder, it can be subjected to evolutionary forces and today it can be properly incorporated into the phylogenetic analyses (7).

Whilst the comparative methods can be used to test hypotheses of adaptation by fitting pre-formulated models to the data and estimating parameters of character evolution (8), phylogenetic regressions can be considered as a fast and robust way to examine relationships among several species and/or environmental predictors simultaneously, while accounting for the non-independence of species as a result of phylogenetic relatedness.

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Functional trait convergence and divergence along climatic gradients in Mediterranean plant communities

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Plant communities are the result of many assembly processes, including ecological and evolutionary ones. Among the ecological assembly processes, two broad categories have been recognised: (a) habitat filtering (1, 2), that restricts the range of viable strategies, and (b) limiting similarity (3, 4), involving the partitioning of resources which imposes limits on the similarity of coexisting species. Such processes can lead to functional trait convergence or divergence, respectively (5, 6). The strength of both processes at the habitat level is modified by large-scale ecological factors and may vary along spatial and temporal gradients, which influence species interactions (7). We aim to identify the patterns of functional trait convergence (or divergence) in selected Mediterranean scrub ecosystems supporting taxonomically different floras, found in regions sharing a relatively similar climatic context. In 2016, we performed the first sampling campaign in Italy (NE-Sardinia), on an altitudinal gradient of 1,300 meters, from the Limbara Massif and surrounding hilly areas to the Tyrrhenian coast: the study area offers the advantage of constant geology along the altitudinal gradient with homogeneous surface morphologies. Given the quite constant edaphic conditions, bioclimate can play a major role in conditioning structure, composition, and processes of the plant communities.

According to (8), we established the transects in four main thermotypes, ranging from upper thermomediterranean to lower supratemperate. In each thermotype, 1 km x 1 km cells, having at least 50% cover represented by scrub vegetation on the basis of the 2008 aerial survey, were randomly selected. Each cell was then divided in 5 m x 5 m plots, three of which were randomly selected per cell. Within each plot, all vascular plant species present and their percentage cover were assessed and recorded in the field.

Specific Leaf Area (SLA), which is associated with environmental tolerance (specifically water stress) and competition for resources, was measured in the field for all the species contributing to the first 80% of cumulative cover within a plot.

As a first overview on the functional structure of the dataset, we summarized shifts in mean SLA values across communities using Community-Weighted Mean (CWM) value per plot (9) and visualized the results using a gridded spatial interpolation. So far, we have detected lower SLA CWM values and variability in coastal areas than the mountainous areas. Differences between the extremes of thermotypes, i.e. upper thermomediterranean and lower supratemperate were significant.

Our first results confirm the importance of the SLA in structuring Mediterranean plant communities across altitudinal gradients. Therefore, assembly rules, which are subject of further investigation, may be assessed using this key trait.

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