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Ecological study of the urban allergenic flora of central Italy

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Abstract

Comparative analysis of allergenic potential, conducted in different urban ecosystems of central Italy, utilizing the species allergen index (SAI), revealed the differences among various urban ecosystems. Allergophyte presence and abundance are influenced by the type and duration of anthropogenic intervention, correlated to the ecological conditions of the individual urban areas and to the level of stability attained. The geographic position of the city and the layout of the urban surfaces present here are also important for the presence of the allergenic flora. The characteristic urbanistic layout of central Italian cities, which is the result of the historical and cultural vicissitudes of the human population, facilitates the establishment of allergophytes. A rich allergenic flora was found on the ancient city enclosure walls with a great risk for the inhabitants suffering from allergies. The influence of the geographic-climatic gradient on the quality of the urban allergenic contingent was observed. The group of strongly allergenic species was found in both the coastal and the hilly-vegetation belt cities. The dynamic contacts with the surrounding ecosystems and ecotonal areas are more accentuated in the cities situated in the internal, hilly zone of the territory studied. Here different potentially allergenic species coming from the surrounding ecosystems become part of the urban flora. The abundance of this flora is noted in the unstable areas of the periphery, where numerous moderately allergenic species were established too. The renewal of the allergenic flora of a city happens thus from within, through the introduction of exotic species in the cultivated areas, and from without, through the spontaneous establishment of plants from surrounding ecosystems. The results obtained can be utilized to indicate the parts of the urban territory which are not suitable for the permanence of persons who suffer from allergic diseases, in order to improve their life quality.

Introduction

The progressive increase of allergenic manifestations in the human population indicates urgent need for research on the presence, distribution and phenology of allergophytes which produce allergenic pollen in the cities. In these places, inhabitants are in direct contact with conspicuous quantities of pollens, the granules of which can cause phenomena of sensitization and allergopathy (Errigo, 1990; Hausen & Vieluf, 1998). There is an increased number of patients suffering from hay fever and allergic bronchial asthma (D'Amato *et al.*, 1991; D'Amato *et al.*, 1992; Ricci *et al.*1993). In addition to contact allergies, frequent in certain occupational categories such as florists, groundskeepers, among others, (Quirce & Sastre, 1998), there has also been an increase in crossed reactions to pollens, dusts and foods (Smid *et al.*, 1992; Eriksson, 1993). Initially, the research focused on the outdoor environment (Negrini & Arobba, 1992) and only recently concern has shifted to exposure of the inhabitants in indoor environment (Platt-Mills, 1994; Portnoy *et al.*, 2001). Thus, the interdisciplinary nature of aerobiology as scientific discipline gives the possibility to enlarge the research field involving different scientists (Mandrioli & Ariatti, 2001).

The urban ecosystems host a rich reservoir of allergenic plants which is continually increasing as various species are brought into the cities accidentally or deliberately by man. Unfortunately, there are few multidisciplinary contributions clarifying the links between the ecological characteristics of the urban environment and man's allergenic illnesses. Some preliminary studies (Hruska & Piarulli, 1995; Leporatti *et al.*, 2000; Telloni & Hruska, 1997) have confirmed the need for a detailed analysis of allergophyte distribution in the individual

urban ecosystems. Entirely lacking, instead, is a comparison of the results for a larger geographic area, in order to verify the influence of the various ecological gradients on the allergenic urban flora and on the quality of life of the inhabitants.

This research takes as its point of departure the various urban ecosystems, utilizing the allergenic index (Hruska, 2003) to express the allergenicity of the species that develop there and, consequently, the phytoallergenic potential of the entire urban area. Through assessment of an allergophyte's distribution in a given city one can identify the urban area to be avoided by allergy sufferers. The research along various gradients (anthropogenic impact and altitude among others) can be utilized in order to indicate the most significant ecological factors for allergophyte dispersion in the urban ecosystems of central Italy taken into consideration during this study.

Study of the dynamic of the allergenic contingent through contacts with extra-urban ecotonal areas enables hypotheses about future development, and forecasts on any eventual probabilities for increased negative effects on the human population. Ecotones are transition, edge zones between adjacent ecological systems (Farina, 1993). The high biological diversity present in the ecotones is important for the exchanges of species between different ecosystems and the renewal of the strongly anthropized areas.

Materials and methods

Ecological studies on the allergophytes were conducted in various urban ecosystems of central Italy (Fig. 1). Table 1 presents the general information on the cities examined. The original data obtained in this research carried out from 2001 to 2005 are put together with those from papers dealing with the flora and vegetation of various urban ecosystems of central Italy (see Appendix). Comparison of results for the peri-urban ecotonal areas includes information taken only from the literature (Hruska, 1995; Rastelli *et al.*, 2003). These data were used to study the dynamic relationships between the urban allergenic flora and that of the surrounding ecosystems. Considering the city as a synecosystem in which space is represented by numerous differing areas formed through the evolution of the individual urban territories, the present study examined the following urban biotopes: walls of the buildings and enclosure walls, trampled areas, arid ruderal sites, roadside verges and shady uncultivated areas. Each species was assigned a specific allergenic index (SAI) sensu Hruska (2003) in the individual habitat, keeping in

Table 1. Some data on the cities studied.

Urban ecosystem	Altitude (m.a.s.l.)	Urban surface (Kmq)	Number of inhabitans
Pisa	4	185	92.000
Civitanova Marche	4	45,57	38.781
Ancona	16	123,71	98.400
Chiaravalle	22	17	14.220
Firenze	50	102	380.000
Jesi	96	108	41.220
Ascoli Piceno	156	158,09	55.000
Foligno	234	55,81	52.400
Spello	280	61,31	8.150
Recanati	293	102	20.000
Siena	322	118	54.400
Orvieto	325	281,16	20.700
Arezzo	350	386	92.300
Spoleto	396	349,63	37.800
Todi	410	221,1	16.910
Urbino	485	227,99	15.100
Perugia	493	444,92	158.300
Norcia	604	274,34	4.915
Cortona	650	35,5	22.400
Camerino	661	129,69	7.284

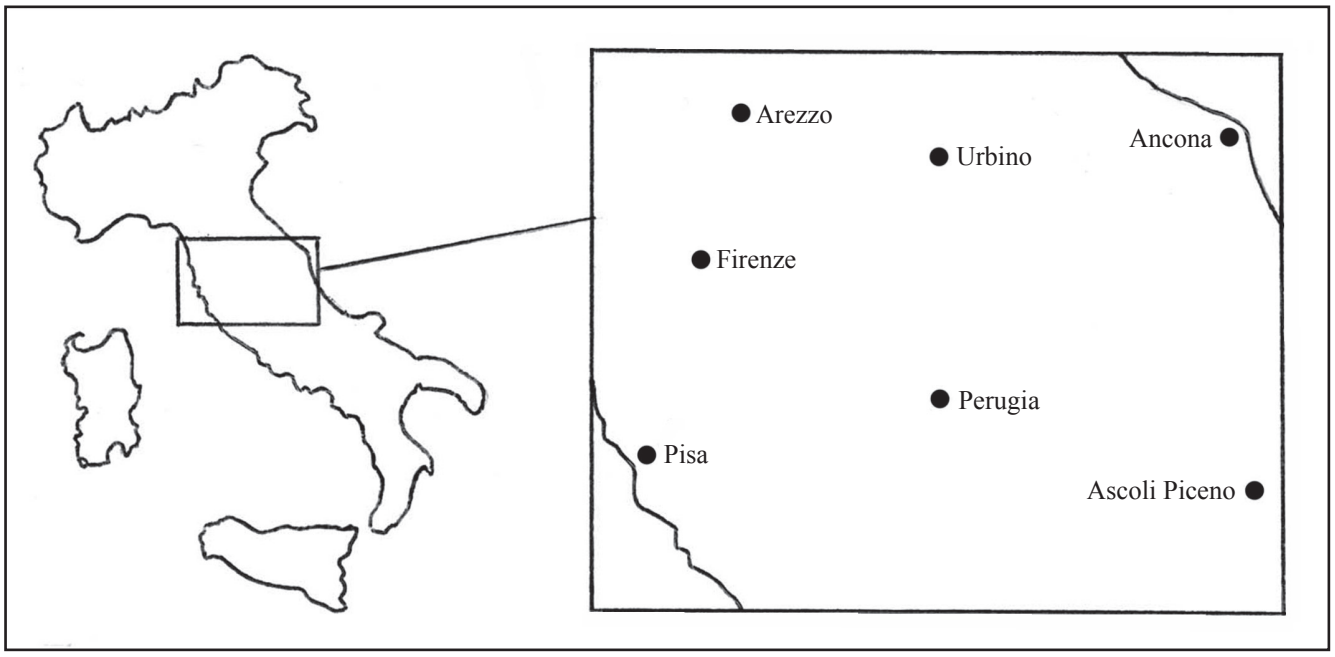

Fig. 1. Geographic location of the study area.

Table 2. Numeric values of the parameters used in evaluating the allergenicity of individual plants (from Hruska, 2003).

Life cycle	Phenanthesic period	Cross reactivity	Abundance
Annuals = 1	less than one month = 0,5	none present = 0	rare = 0,5
Biennials = 2	more than one month = 2	present = 1	present = 1
Perennials = 3			rather common = 2
			abundant = 3
			very abundant = 4

mind its life cycle, length of the phenantesic period, presence of phenomena of cross reactivity and abundance. These parameters were assigned numeric values in ascending order, which express the potential of a plant species, through its pollen, to cause allergic manifestations in man (Table 2). The allergenic index (SAI) is the sum of the pre-chosen values for each of the partial characteristics outlined above. On the basis of the numeric value of the allergen index, three groups of plants can be identified: strongly allergenic (SAI = 7-10), moderately allergenic (SAI = 4-6) and slightly allergenic or of uncertain effect (SAI $\leq$ 3). Starting from the species list developed for a certain biotope, the overall allergenicity of the biotope was evaluated, expressed as the average of the specific indices obtained for all the allergophytes found in a certain urban biotope.

Cluster analysis of these tables was done using the PAL-STAT (Ryan *et al.*, 1995) statistical program. The dendrograms were obtained with the UPGMA algorithm (unweighted paired group average) using Euclid's similarity index. Correspondence analysis was used to study allergophyte distribution along various gradients (altitude, anthropogenic impact, humidity and aridity).

Results

Phytoallergenic potential of urban ecosystems

Comparative analysis of the data obtained in various urban ecosystems served to clarify the relationship between the ecological characteristics of the allergenic flora and the urbanistic typologies of the cities of central Italy. In all the cities studied the prevalence of moderately allergenic species, followed by those that are weakly or strongly allergenic is observed (Fig. 2). The greatest percentage of strongly allergenic species was noted in the uncultivated shady areas (25%) and on the enclosure walls (18.5%), followed by the arid ruderal sites (10%). The plants with very allergenic pollen are prevalently species of the *Graminaceae* and the *Compositae* families which are becoming ever more abundant in the cities, due to the particular urban climate (Palmieri & Siani, 2000). One group of *Graminaceae* (*Dactylis glomerata* L., *Hordeum murinum* L., *Hordeum leporinum* (Link) Arcang., *Elytrigia repens* (L..) Nevski, *Cynodon dactylon* (L.) Pers., *Lolium perenne* L., *Poa annua* L.), some of which are characterized by cross reactivity as well (Ortolani *et al.*, 1993; Van der Veen *et al.*, 1997; Chappard *et al.*, 2004), are very frequent in all the cities.

In Figure 3, which gathers the results, one can observe a notable overall allergenicity in the uncultivated shady areas (average SAI value = 5,51). Here, the constant presence of abundant and strongly allergenic species was observed (*Parietaria officinalis* L., *Urtica dioica* L., *Artemisia vulgaris* L., *Artemisia verlotorum* Lamotte, *Poa pratensis* L., among others). Different species of the family of *Urticaceae* are studied as allergenic in Spain (Trigo *et al.*, 1996). On the enclosure walls, instead, the allergenic index of the biotope is slightly lower (average SAI value = 5.46). Here, in addition to

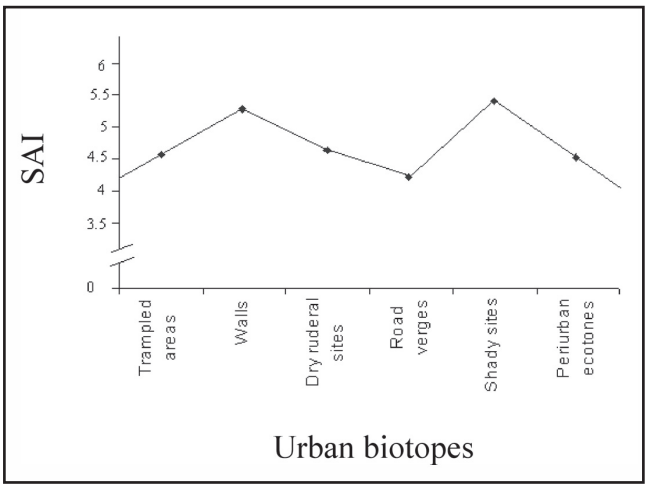

Fig. 2. Phytoallergenic potential of the urban ecosystems of central Italy expressed through the species allergenic index (SAI).

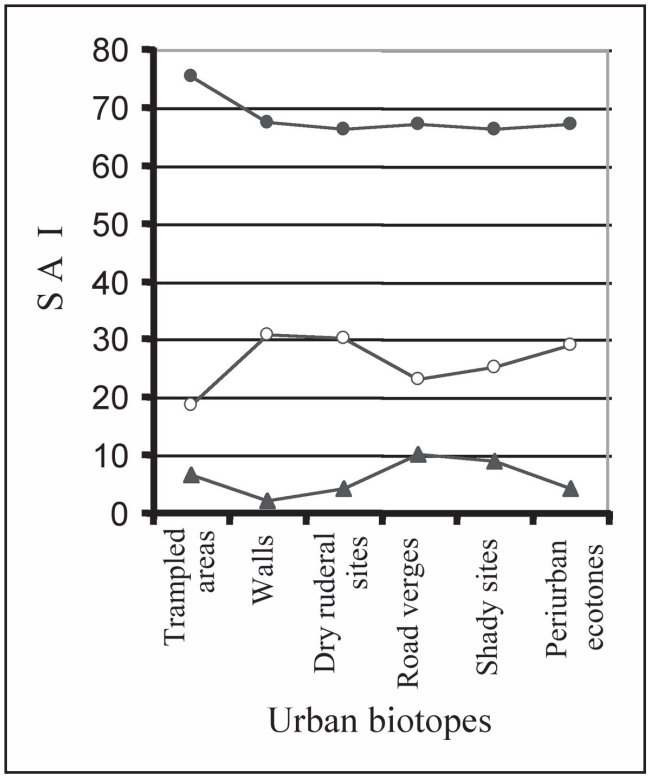

Fig. 3. Species allergenic index (SAI) of the urban biotopes of central Italy: average data for the cities studied, (black circles: moderately allergenic species, white circles: strongly allergenic species, black triangles: slightly allergenic species).

Parietaria diffusa M. et K., a urban plant known for its great allergenicity a group of species characteristic of the biotope grows, such as *Capparis spinosa* L., *Centranthus ruber* (L.) DC., *Cymbalaria muralis* Gaertn., Mey. *et* Sch., *Reichardia picroides* (L.) Roth, *Antirrhinum majus* L., *Diplotaxis tenuifolia* (L.) DC. and other species.

The trampled areas are characterized by low allergenicity (Fig. 2).

Ecological characteristics of the urban allergenic flora

Numerical processing of the data on the presence and abundance of the urban allergophytes in the cities studied has revealed some gradients with direct influence on the urban phytoallergenic potential. An anthropogenic gradient moving from the centre toward the urban periphery was identified. The presence of urban allergophytes along this gradient is influenced by the type and duration of the anthropogenic intervention. For example, Figure 4 presents distribution of allergophytes along the street and road verges, correlated to the degree of anthropization. It can be observed that the allergophytes are more abundant on the verges exposed to a moderate, not very varied disruption. Instead, there is a reduction in the percentage of allergophytes along strongly disturbed road verges, where the type and duration of anthropogenic disturbance change frequently. Since anthropogenic intervention also influences the pedological conditions of this biotope, a pedological gradient is found here, as well (fine texture of the soil-moderate disruption, rough texture-strong disruption). Thus, because of the latter gradient, the species heterogeneity increases.

In the dendrogram (Fig. 5), obtained from processing the data on the phytoallergenic potential of the city walls and the walls of the buildings of the urban ecosystems studied, an altitudinal gradient correlated to some local microclimatic parameters (humidity, aridity, luminosity and others) was observed. On the left side of the dendrogram the cities of the hilly vegetation belt, such as Camerino, Urbino, Perugia, Siena, Todi and Cortona, form a group. On the right there are the data taken on the moderately sunlit and arid walls of the cities in the lower hilly vegetation belt and the coastal one, both Adriatic and Tyrrhenian. So, the ecosystems of Recanati, Jesi, Ancona, Chiaravalle, Ascoli Piceno, Spello, Florence, Pisa and others are assembled together (see Fig. 1.).

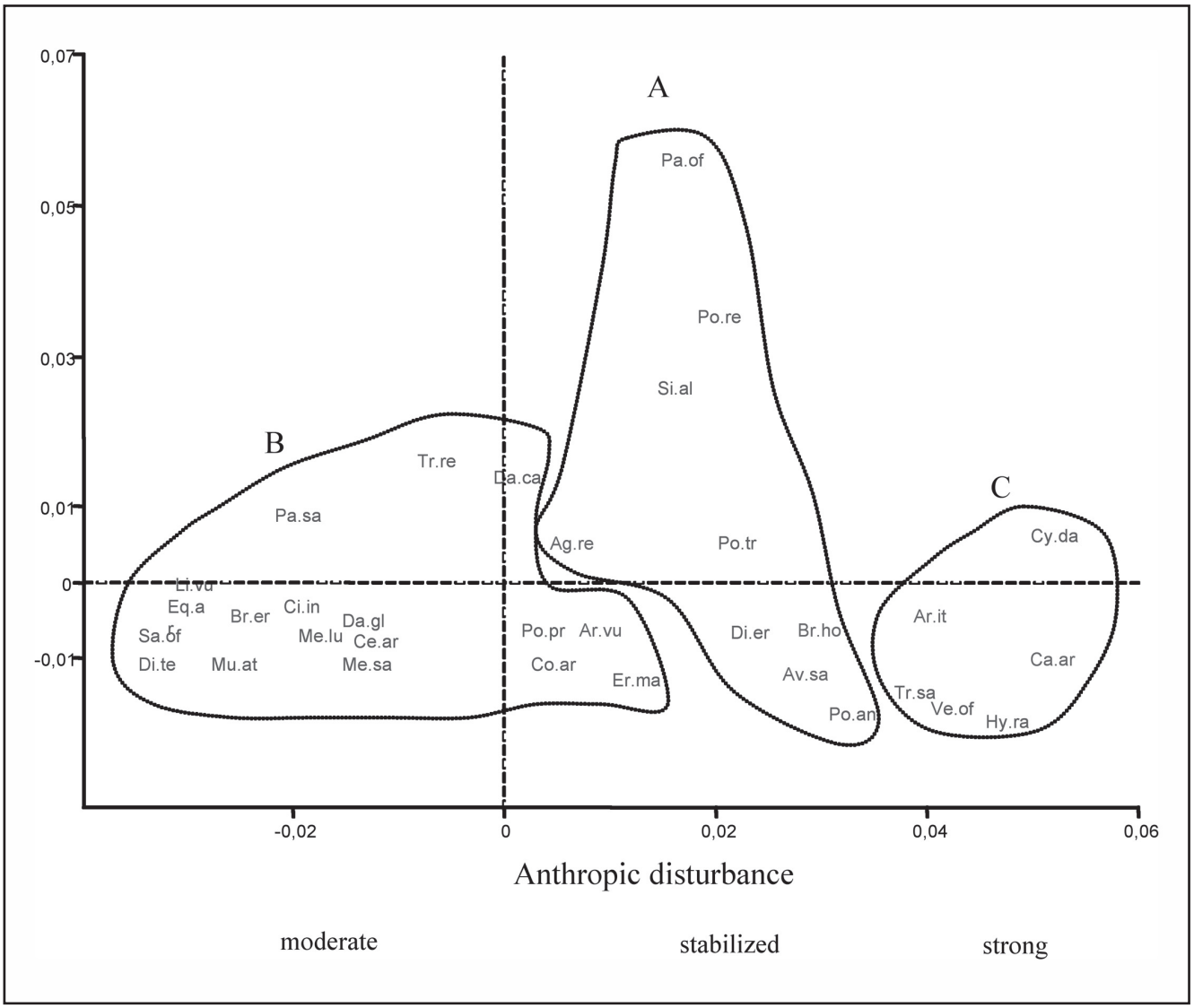

Fig. 4. Ordination of the allergophytes on the urban road verges based on correspondence analysis – A: stabilized anthropogenic disturbance, B: moderate anthropogenic disturbance, C: strong anthropogenic disturbance (Abbreviations of the species: Pa.of = *Parietaria officinalis* L.; Av.sa = *Avena sativa* L.; Br.hr = *Bromus hordeaceus* L.; Cy.da = *Cynodon dactylon* (L.) Pers.; Da.gl = *Dactylis glomerata* L.; Po.an = *Poa annua* L.; Po.pr = *Poa pratensis* L.; Po.tr = *Poa trivialis* L.; Di.te = *Diplotaxis tenuifolia* (L.) DC; Ar.vu = *Artemisia vulgaris* L.; Ca.ar = *Cardaria draba* (L.) Desv.; Da.ca = *Daucus carota* L.).

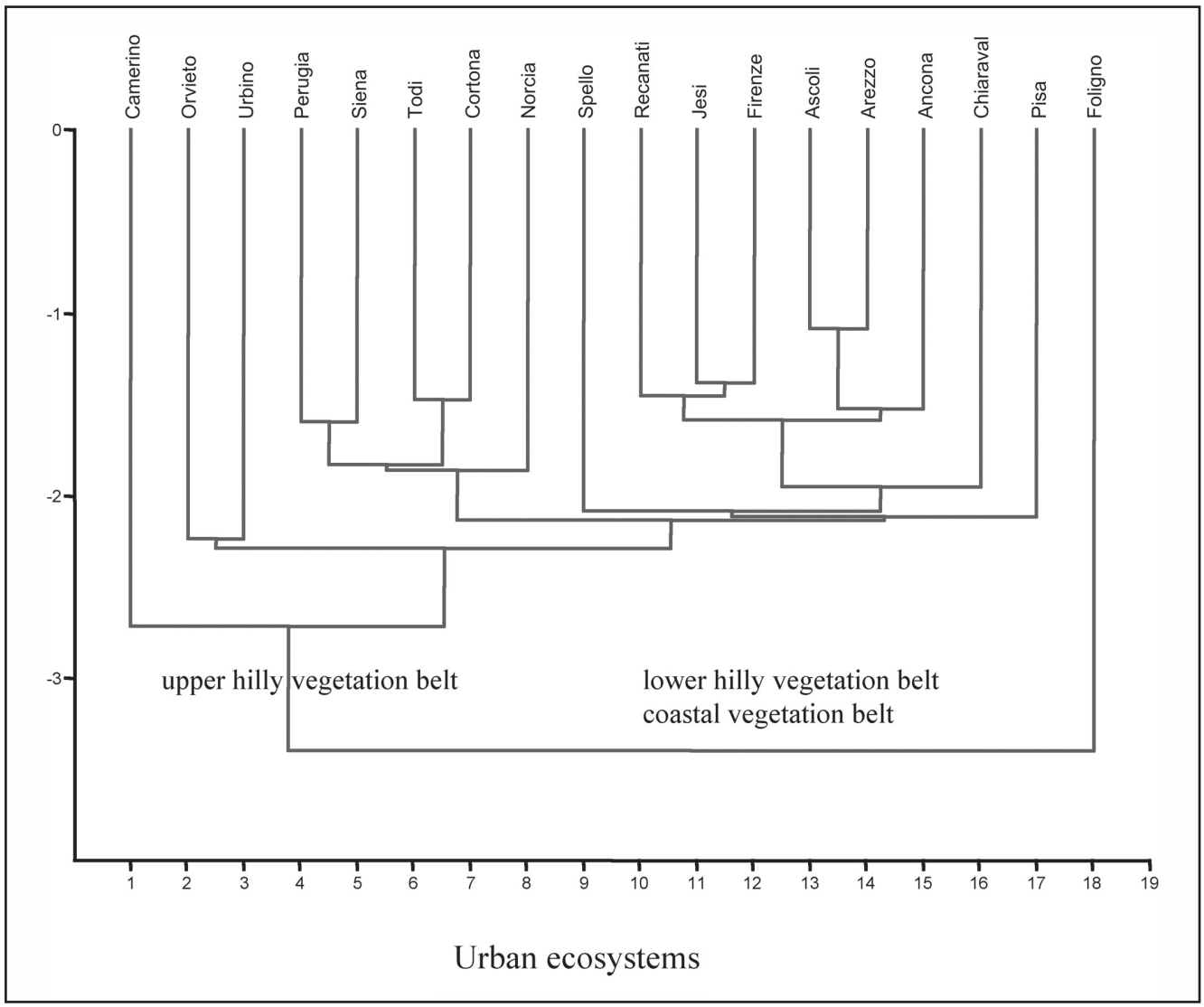

Fig. 5. Ordination dendrogram of the allergophytes growing on the enclosure walls of the central Italian cities based on the similarity ratio. (Two principal groupings of the urban ecosystems arranged in different vegetation belts can be noted).

Dynamics of the urban allergenic flora

The dynamic contacts between the cities and the surrounding ecosystems and ecotones provoke a continuous renewal of the urban vegetal component.

It was noted that most allergophytes penetrate the city from arid pastures and the forest ecosystem. From the grazing lands come the species of the *Graminaceae* and the *Compositae* families, which establish themselves in arid and sunlit sites.

The shady uncultivated areas, instead, are colonized by various herbaceous species of the *Umbelliferae* family, such as *Chaerophyllum temulum* L., *Aegopodium podagraria* L., *Anthriscus nemorosa* (Bieb.) Sprengel, the allergenic effect of which on the inhabitants has not yet been studied, but it could be probably caused by abundant pollen production.

Connectivity between ecotonal areas, forest ecosystems and cities facilitates the flow of nemoral species towards anthropized areas.

In the urban ecosystems which conserve in the own territory (e.g. Jesi, Camerino, Ascoli Piceno, Urbino, Norcia) the fragments of the natural vegetation, the entrance of these species is more evident.

Discussion

There is a direct linkage between the allergenic flora and the common urbanistic characteristic of the cities of central Italy here studied. The central urban zone (houses built almost one close to the other, paved streets, scarcity of green areas), do not foster, for example, the establishment of a rich allergenic flora. The local ecological conditions become the predominant factor for the presence of allergophytes. The allergenicity of this zone can increase through cultivated areas with plants of exotic origin, often with cross reactivity, as is the case of the *Cupressaceae* family (Zerboni *et al.*, 1991).

On the ancient enclosure walls, instead, *Parietaria diffusa*, the allergophyte with known pollen specific and cross-reactive allergens (Accorsi & Bandini Mazzanti, 1980; Stumvoll *et al.*, 2003) is very abundant. The presence here of many small ferns that prefer humid and shady areas, such as *Asplenium ruta muraria* L., *Asplenium trichomanes* L., *Adiantum capillus veneris* L, should be underlined. This means that in the urban ecosystems of the hilly zone, the effect of the urban heat island is not very accentuated (Palmieri & Siani, 2000) and does not yet provoke the disappearance of the ferns, as happens in the large European cities. In fact, in the metropolises, because of this phenomenon, the urban climate

is fairly arid, and does not promote the development of these species. Different anemochores Compositae (e.g. *Taraxacum officinale* Weber, *Helichrysum italicum* (Roth) Don, *Anthemis tinctoria* L. and *Sonchus oleraceus* L.) make up the wall flora, inasmuch as the enclosure walls represent a barrier to the circulation of air masses, especially in these urban ecosystems situated on hills. The cities of the hilly vegetation belt host a characteristic wall flora formed of some strongly allergenic species for the onset of allergopathies in man, and a notable percentage of moderately allergenic ones, as explained previously. Their considerable abundance here intensifies probably their allergenic effect on the inhabitants.

Some preliminary results of our research on the relationship between the phenology of these plants and the epidemiological data on the allergies of the human population seem to confirm this fact (Telloni & Hruska, 1997).

The dynamic links between urban ecosystems on the one hand and arid grazing lands and forests on the other facilitate the establishment of various, potentially allergenic species in the cities. The shady uncultivated areas host a flora that has shifted, by means of the ecotonal areas, from the woods to the city. This dynamic process is more accentuated in the cities situated in the internal, hilly vegetation belt. Here different potentially allergenic species enter to make part of the urban flora. Their luxuriant development leads to the production of considerable quantities of pollen that could cause increased difficulties for sensitized subjects. Given the lack of data on this aspect, it would be appropriate to conduct further research.

Conclusions

From quantitative and qualitative analysis of the allergenic flora, conducted in different urban ecosystems of central Italy, one can deduce that the urban phytoallergenic potential is influenced by various factors. The most important among these are:

- The type and duration of human impact, correlated to the ecological conditions of the individual cities and to the level of stability attained,
- The geographic position of the city,
- The layout of the urban surfaces and the type of ecosystems in the surrounding zones.

The complex environmental situation in urban settlements is reflected in allergophytism. For the evaluation of the phytoallergenic potential in certain parts of the urban surface, the comparison of the specific allergenic indices was very useful. It can be deduced that most dangerous areas for the onset of allergenic manifestations in the inhabitants are the ecologically stabilized ones such as city enclosure walls, which host some strongly allergenic urban species. In the peripheral zones (road verges, uncultivated areas), unstable and strongly dynamic, an elevated presence of moderately allergenic species was noted. These areas, forming as they do part of the ecological corridors of the territory, facilitate the entrance of allergophytes from the surrounding ecosystems and thus represent reservoirs for the renewal of the phytoallergenic potential of the individual urban ecosystems, increasing, consequently, the risk of contact between this flora and sensitive subjects.

The urban layout typical of central Italian urban ecosystems facilitates the establishment of allergophytes within the urban area. In the central areas of towns without enclosure walls, a low percentage of spontaneous allergophytes was observed. Allergophytism of this part of the urban territory can increase through cultivated 'green areas', formed of exotic plants that are present because of historic and cultural factors.

It has been revealed that the urban periphery is less suitable as a residential/work area for the inhabitants suffering from allergenic manifestations. Here the human population is in contact with typically urban allergophytes as well as those that have penetrated from surrounding ecosystems. Utilizing these results, prevention and treatment measures for persons who suffer from allergic manifestations caused by urban pollen can be better defined, avoiding especially their permanence in the unsuitable urban zones.

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