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Dedicated to Prof. dr. LJUDEVIT ILIJANIĆ on the occasion of his 70th birthday.

Relationship between pollen spectrum and vegetation in the Friuli-Venezia Giulia region (NE Italy)

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A qualitative and quantitative analysis of airborne pollen in four sites of the Friuli-Venezia Giulia region (NE Italy) is presented. The pollen was collected in 1984 with Cour traps. Most pollen types in the atmosphere of the studied sites are from woody species; a less important proportion comes from herbaceous species. The most abundant pollen types are: *Cupressaceae*, *Ostrya*, *Moraceae*, *Pinaceae*, *Urticaceae*, *Graminaceae*, *Betula*, *Platanus*, *Quercus* and *Castanea*. Trieste is quite different from the other sampling sites, both for the higher values of overall pollen counts and for the superabundant pollen shedding of *Cupressaceae, Ulmaceae, Ostrya, Quercus, Moraceae, Oleaceae, Pinus, Castanea, Graminaceae, Urticaceae* and other minor taxa. Udine often proves similar to Trieste, although the sites have different pollen count values. The sampling site is characterised by more intense pollen shedding by *Corylus*, *Carpinus*, *Platanus* and *Fagus*. Latisana is characterised by the particular abundance of *Alnus* and *Salicaceae* pollens, and for the overall low pollen counts. Tolmezzo is quite different from the other sampling sites; the main differences are in the patterns of the pollen counts for the taxa considered and in the time of pollination peaks.

Key words: aerobiology, pollen, flora, Friuli-Venezia Giulia, Italy

Introduction

Friuli Venezia Giulia, the Italian region in the northeast of the country, has a rather varied geography, climate, and vegetation, despite the small area it covers (ca. 8500 km^2). The airborne pollen of a given site is related to the local vegetation. Therefore, the authors have judged it interesting to compare the air pollen content of different sampling sites, each representative of one of the phytogeo-

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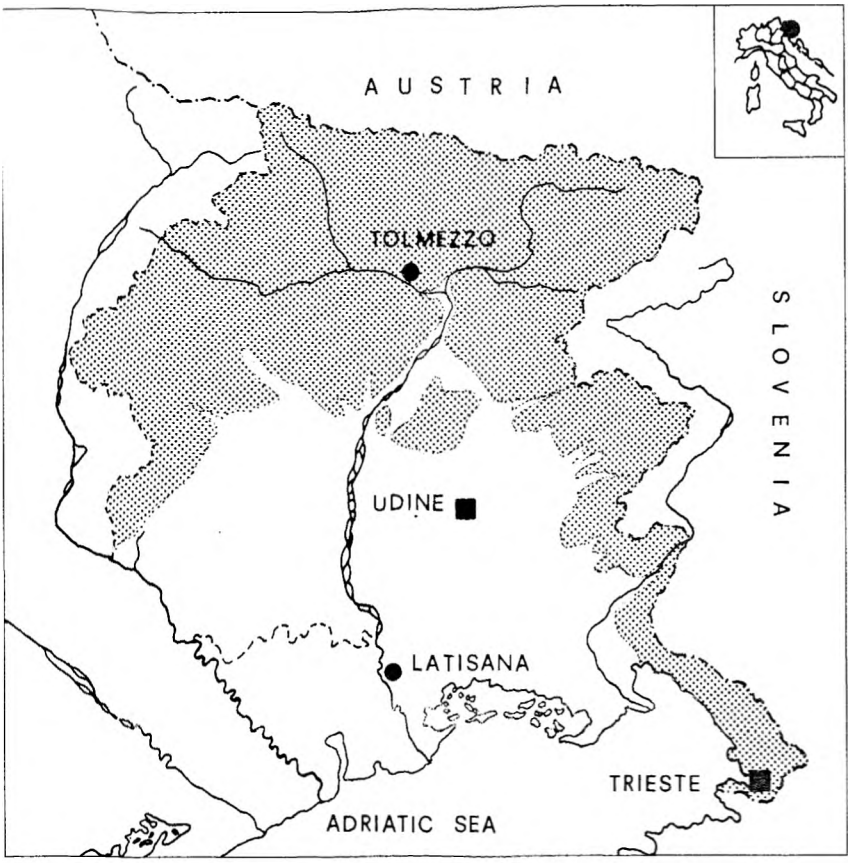

Fig. 1. Geographic location of the study sites.

graphic districts of the region (Fig. 1). The following four locations were chosen: the town of Trieste, situated on the coast of the Adriatic Sea and surrounded by the karst plateau, representing the Mediterranean (coastal) district and the Illyrian-Dinaric (karst) district; the town of Udine, in the Upper Friuli Plain, close to the morainic hills of the Tagliamento River and to the first Carnic pre-Alps, representing the plain and pre-Alp (hill) district; Latisana, in the Lower Friuli Plain, surrounded by cultivated land and close to the sandy coast round the villages of Lignano and Bibione, representing the plain district; Tolmezzo, situated in the northern part of the region, surrounded by mountains, representing the ex-Alpic district.

Airborne pollen in Trieste has been monitored continuously since 1978 (RIZZI LONGO et al. 1980, RIZZI LONGO and COASSINI LOKAR 1985, RIZZI LONGO and CRISTOFOLINI 1987, RIZZI LONGO 1990, LARESE et al. 1992, 1998). The other sites were monitored from 1982 through 1984, and the results have been published only partially (RIZZI LONGO et al. 1987).

Outlines of climatology

The climatic data here exposed is drawn from the works of GENTILLI (1964), POLLI (1970, 1971) and ZANETTE (1995). The climatic phenomena that mostly affect the diffusion of airborne pollen are air temperature, rainfall and winds at ground level. For each of these, the maximum and minimum monthly means and annual mean of each sampling site are given.

The town of Trieste stands on a narrow arch between the coast of the Adriatic Sea and the base of the karst plateau that encircles the town north and east. Both the sea and the plateau are crucial in determining the local climatic conditions. The mean annual temperature is the highest among those of the sites considered (14.2 °C); the minimum occurs in January (4.7 °C) and the maximum in July (24 °C), although the August mean temperature is only slightly lower (23.6 °C). Rainfall is spread over 93 days, with a mean of 952 mm per year; minimum rainfall occurs in March (57 mm), while the maximum occurs in October (109 mm); a local maximum occurs in June (96 mm). Winds are mainly easterly, the most important being the bora (ENE). On the karst plateau that rises behind the town the climate is somewhat different. In Opicina (320 m above sea level), the largest village of Trieste's Karst, the minimum monthly mean falls to 1.4 °C, while the maximum monthly mean and the annual mean are 20.9 °C (July and August) and 11.5 °C, respectively. Rainfall is higher than in Trieste, with a mean of 1222 mm per year, spread over 108 days. Winds, and especially the bora, are weaker than in Trieste.

Latisana (7 m a. s.) is situated in the Lower Friuli Plain, on the left bank of the Tagliamento River, where the river follows the western border of Friuli-Venezia Giulia. Even though it varies throughout the year, the local climate is mitigated by the nearby (ca. 10 km southward) Adriatic Sea and Marano Lagoon. However, the mitigating effect of the sea is reduced because of the shallow waters. The climatic data is therefore characterised by higher temperatures and less intense rainfall, compared to the Upper Friuli Plain. Mean monthly temperatures reach their minimum in January (3.5 °C) and their maximum in July (23.6 °C), while the annual mean is 13.8 °C. Mean annual rainfall is 1098.2 mm (spread over 95 days), with the minimum in February (61.9 mm), a local maximum in June (114.9 mm) and the absolute maximum in October (124.1 mm). Dominant winds are easterly (quadrant I), although sea breezes are also conspicuous, especially during summer. Days of calm (wind speed < 0.5 m/sec) are more frequent in winter (December-February).

The town of Udine (136 m a. s.) is situated in the eastern part of the Upper Friuli Plain; the annual mean temperature is 12.4 °C, with the minimum temperature in January (2.3 °C) and the maximum in July (21.8 °C), although the highest daily temperature range (11.8 °C) occurs in August. Rainfall is spread over 98 days, with an annual mean of 1401 mm; minimum rainfall occurs in February (71.3 mm), a local maximum occurs in May (143.2 mm) and the absolute maximum occurs in November (146 mm). Dominant winds blow mainly from the first quadrant. Days of calm occur mostly from November through January.

The village of Tolmezzo (323 m a. s.) is situated at the foot of Mount Amariana, on its west side, on the left bank of the But Torrent, a little upstream

from where it pours into the Tagliamento River. The extension of the territory and its orographic complexity make climatic conditions highly variable from site to site. The data presented here refer only to the village of Tolmezzo. The mean annual temperature is 10.6 °C, the minimum monthly mean occurs in January (–0.03 °C), while the maximum occurs in July (19.9 °C). The maximum daily temperature range occurs in August (10.9 °C). Mean annual rainfall is 2103 mm spread over 108 days; minimum rainfall occurs in January (93 mm); a local maximum occurs in May (207 mm), while the absolute maximum occurs in November (285 mm). Days of strong wind are scarce (8), and breeze regimes prevail.

Outlines of vegetation structure in the study area

Given the subject of this study, a description of vegetation structure must be limited to the fundamental communities found in the surroundings of the sites where pollen was collected. Particular attention is given to the vegetation units where plants with allergenic pollen are found.

The vegetation structure of Trieste's seaboard, of the Karst and of the marl and sandstone hills that lie behind the town is characterised by the contrast and the coexistence of two vegetation cycles: Euro-Siberian vegetation and Mediterranean vegetation (POLDINI 1989). This phenomenon is strong enough to differentiate Trieste's vegetation from the vegetation of the other sampling sites. On the coast, hop hornbeam and holm oak woodland prevails, a sclerophyll formation close to *Quercetea ilicis*, whose main feature is the coexistence of Mediterranean elements such as *Quercus ilex*, *Phillyrea latifolia*, *Pistacia terebinthus* and *Acer monspessulanum*, and eastern elements, usually found in Illyrian sub-Mediterranean flora, the most important of which are *Fraxinus ornus*, *Ostrya carpinifolia*, *Carpinus orientalis*, *Paliurus spina-christi*, *Cotinus coggygria* and *Coronilla emerus* subsp. *emeroides* (LAUSI and POLDINI 1962). Leaving the coast, Trieste's vegetation, as well as the rest of the region's, belongs to the temperate climate Euro-Siberian-North-American cycle. Broad-leafed woodlands thus belong to the class *Querco-Fagetea* and are represented mainly by mixed mesophilous and thermophilous oak woodlands belonging to the *Ostryo-Carpinion orientalis* alliance. The most frequent is hop hornbeam-oak woodland with smoke trees (*Ostryo-Quercetum pubescentis*), which covers most of the karst plateau, and, in part, flysch slopes with humus-poor soils (POLDINI 1989). The principal species are *Ostrya carpinifolia*, *Quercus pubescens*, *Fraxinus ornus*, *Acer campestre*, *Celtis australis*, *Ulmus minor*, *Sorbus aria*, *Quercus cerris*, *Carpinus orientalis*, *Acer monspessulanum*, *Tilia platyphyllos*, *Cotinus coggygria* and *Ligustrum vulgare*. In mesothermic edaphic conditions, autumn moor grass and oak woodlands with *Quercus petraea* are common; other species found are *Q. cerris*, *Q. pubescens* and *Ostrya carpinifolia*. In this association, mesophilous elements are more common, even if in different floristic contexts, due to different soil acidification. Elements of the *Erythronio-Carpinion* alliance, discontinuously, and with extrazonal characteristics (*Asaro-Carpinetum betuli*), cover the base of southern doline slopes, at medium or medium-high depths. The *Aremonio-Fagion* alliance is very frequent in the Slovenian Karst, where beech woods, or mixed beech and silver fir woods dominate the montane

vegetation structure. *Pinus nigra* deserves special mention, as it was introduced into the Karst by man, starting in the mid-19th century, in vast plantations meant to reforest the area; this species has now become spontaneous. The most frequent herbaceous formations are the result of the contrast between two vegetational elements. One is represented by thermophilous formations growing on humus-poor soils, which POLDINI (1989) judges to be close to the thermophilous alliances *Scorzonerion villosae* and *Satureion subspicatae*. The other element is represented by *Molinio-Arrhenatheretea* grassland, where middle-European mesophilous elements are concentrated (POLDINI 1989). Today, herbaceous vegetation is rapidly disappearing because of the decline of agriculture, forestry and sheep-breeding (FAVRETTO and POLDINI 1985). Anthropogenic associations, such as *Artemisietea*, *Chenopodietea*, *Plantaginetea majoris*, *Agropyretea intermedii-repentis* and *Parietarietea* are frequent, due to the broadening of urban areas, frequent disturbance of territory (such as the construction of roads, highways and industrial ducts) and the presence of agricultural and horticultural activities. These associations include highly allergenic genera such as *Artemisia*, *Ambrosia*, *Rumex*, *Polygonum*, *Chenopodium*, *Plantago*, *Parietaria*, *Urtica* and many other mostly North-American neophytes (MARTINI and POLDINI 1995). Other allergenic plants, cultivated for ornamental or commercial purposes (such as *Cupressus*, *Thuja*, *Cedrus*, *Olea*), which frequently become spontaneous (such as *Aesculus* and *Broussonetia*) contribute to airborne allergenic pollen (D'AMATO et al. 1991) as well.

The climax vegetation of the Lower Friuli Plain is represented by oak and hornbeam plain forests (*Asparago-Quercetum roboris*), where the tree species, apart from *Quercus robur* and *Carpinus betulus*, are *Fraxinus oxycarpa*, *Acer campestre*, *Ulmus minor*, *Prunus avium*, *P. padus*, *Alnus glutinosa*, *Sorbus torminalis* and *Populus tremula* (PIGNATTI 1953, DEL FAVERO et al. 1998). Although very important from an ecological and phytogeographic point of view, the extension of this type of vegetation is limited, due to its progressive replacement by cultivated land; this association now survives as relict vegetation (PAIERO 1965). Formations dominated by *Alnus glutinosa* and *Fraxinus oxycarpa*, still found along the main resurgence rivers or in plain forests, may probably be included in hygrophilous facies of oak and hornbeam woods. Riparian vegetation is much more frequent, and is represented by various willow formations. Such formations are mainly riparian woods of *Salix alba* and *Populus alba* (*Salicetum albae*) and riverbank scrubs dominated by shrubby willows such as *Salix purpurea*, *S. cinerea*, *S. triandra* (*Salicion cinereae*). Natural vegetation is little represented in the Lower Friuli Plain, due to the high exploitation of the territory, which hosts mainly urban and industrial areas, and intensively cultivated land. Thus, anthropogenic vegetation formations are frequent and mainly represented by *Artemisietea*, *Chenopodietea*, *Plantaginetea majoris*, *Bidentetea* and *Agropyretea intermedii-repentis*. Hedges (*Prunetalia*) are frequent where cultivated land is still divided into closed fields; these barriers also host *Carpinus betulus*, *Acer campestre*, *Ulmus minor*, *Quercus robur*, *Crataegus monogyna*, *Cornus sanguinea*, *Prunus domestica*, *P. avium*, *P. mahaleb*, *P. spinosa*, *Ligustrum vulgare* and *Rosa sp. pl.*. Fertilised grasslands (*Arrhenatherion* and *Cynosurion*) still find some place, along with wet meadows (*Filipendulion*), herbaceous river-

bank (*Agrostietea*) and hygrophilous (*Phragmition* and *Magnocaricion*) formations.

The natural vegetation of Udine's countryside is also much compromised by the expansion of urban and industrial areas and of intensive agriculture. Thus, the vegetation has in part the same characteristics as the vegetation of the Lower Friuli Plain, along with herbaceous vegetation belonging to the xerothermic grassland locally called »magredi« (FEOLI CHIAPELLA and POLDINI 1993). The closest extensive woodland is in the hill and mountain region that encircles Udine on its east side, from the village of Cividale to the village of Tarcento, ca 15 km from town, where mostly marl and sandstone soils are found. Depending on altitude, exposure and position, these woodlands have different floristic compositions, which give rise to numerous phytosociological units. Between 100 and 700 m above sea level, mixed hardwood forests prevail, mostly oak woods and hornbeam woods in which the chestnut (*Castanea sativa*) is dominant. This species strongly affects the appearance of these woodlands: sub-montane chestnut woods (*Ornithogalo pyrenaici-Carpinetum betuli*) and chestnut and ash woods (*Hacquetio epipactido-Fraxinetum excelsioris*), for example, are among the most frequent woodlands of the region. The species that may be found more frequently, even if in different relative amounts, due to the different phytosociological formations are *Castanea sativa*, *Fraxinus excelsior*, *Quercus petraea*, *Carpinus betulus*, *Ulmus glabra*, *Tilia cordata*, *Prunus avium*, *Populus tremula*, *Sorbus torminalis*, *S. aria*, *Acer campestre*, *Quercus robur*, *Ulmus minor*, *Robinia pseudacacia*, *Betula pendula*, *Corylus avellana* and *Crataegus monogyna*. As altitude rises, or in cooler exposures, sub-montane beech woods become more frequent, while other formations, such as maple and ash woods or flowering ash and hop hornbeam woods are only marginally present.

The vegetation structure of the surroundings of Tolmezzo is dominated by natural or near natural vegetation, if compared to the highly anthropogenic vegetation of the Plain. The high number of biotopes that may be found, derived from the complex geomorphological situation, allows only a brief description of the most characteristic vegetation formations, starting with woodlands. The hill and sub-montane zone is dominated by thermophilous woods with *Ostrya carpinifolia* (*Seslerio albicantis-Ostryetum*, *Buglossoido purpurocaeruleae-Ostryetum*) and by natural pinewoods composed of *Pinus nigra* (*Fraxino orni-Pinetum nigrae*). *Fraxinus ornus*, *Quercus pubescens*, *Sorbus aria*, *Tilia cordata*, *Acer campestre*, *A. platanoides* and *A. pseudoplatanus* are also frequent. Less frequent are pinewoods of *Pinus sylvestris*, either alone or with *P. nigra*; the understory of these woods is composed of heath (*Erica erbacea*). Among secondary formations, brome herbaceous formations correspond to these phytosociological units, with different compositions (FEOLI CHIAPELLA and POLDINI 1993). Mesophilous woods are represented mainly by sub-montane and montane beech woods, between 500 and 1800 m a. s. Even if in different ecological contexts, the main tree species are *Fagus sylvatica*, *Acer pseudoplatanus*, *Sorbus aria*, S. *aucuparia*, *Fraxinus excelsior*, and sometimes *Picea abies*. The corresponding herbaceous formations include the mesophilous extreme of brome formations (*Scorzonerion villosae*), hay fields (*Polygono-Trisetion*) and pastures (*Poion alpinae*). The most common softwood forests are introduced spruce

woods, derived from montane beech woods, through a forestry management that has privileged coniferous trees, and particularly *Picea abies* (DEL FAVERO et al. 1998). Other softwood forests deserving mention are exalpic montane and sub-montane fir woods, characterised by the presence of *Abies alba* and *Fagus sylvatica*; these woods, depending on altitude and exposure, may also include *Acer pseudoplatanus*, *Fraxinus excelsior*, *Sorbus aria*, *S. aucuparia*, *Ostrya carpinifolia*, *Picea abies*, *Sambucus racemosa* and species of the genus *Lonicera*. Above the timberline, *Pinus mugo* and *Rhododendron hirsutum* scrub formations are frequent, *Larix decidua* and willow scrubs of *Salix glabra*, *S. appendiculata* or *S. waldsteiniana* also being present. At higher altitudes natural grasslands, included in the *Caricion australpinae* alliance (*Seslerietea albicantis*) take over. Finally, because of the presence of numerous torrent beds, flood bed formations are frequent. These are mainly mixed willow scrubs with *Salix daphnoides*, *S. eleagnos*, *S. purpurea* and alder scrubs composed of *Alnus incana*.

Materials and methods

Pollen was collected in 1984, using a Cour trap, placed at about 20 m above the ground, in the town or village centre, in all four sampling sites. In Trieste, the trap was placed on the Bastione Fiorito, inside the Castle of San Giusto, while in Udine, Latisana, and Tolmezzo, the traps were placed on the roof terraces of the respective hospitals. The vertical filters were collected weekly and treated according to Cour's method (COUR 1974); the last phase of this method consists in mounting the acetolysed pollen grains in a semi-mobile preparation; the correct identification of a great number of pollen types is thus made possible. Further information on this method may be found in RIZZI LONGO and CRISTOFOLINI (1987), MEINFREN (1988), BELMONTE and ROURE (1991), GONZALEZ MINERO et al. (1998) and GUSTAVSSON (1998). The microscopic identification of the pollen types was carried out through comparison with a type collection of well documented samples of pollen grains and using MOORE et al. (1991). The resulting data are weekly pollen concentrations. For a comparison among the four sampling sites, the pollen count resulting from pollen identification is expressed as number of grains per square meter, since wind speed was only known for Trieste. The concept of the main pollen season was used. After NILSSON and PERSSON (1981) the main pollen season is the period between the day when the cumulation of the daily means reaches 5% of the total annual sum until the day when it reaches 95%. In the tables of the different aeropalynological parameters of the pollen spectra and in the results, the taxa are presented in alphabetical order. In the pollen calendar (Figs. 2–7), the taxa are ordered following the chronological succession of peaks.

Systematic nomenclature follows the works of EHRENDORFER (1973) and PIGNATTI (1982), while syntaxonomic nomenclature mostly follows POLDINI (1989), POLDINI and VIDALI (1995) and DEL FAVERO et al. (1998). For a description of the phytogeographic districts of the region, see POLDINI (1987).

Results

Airborne pollen grains captured weekly in the four sampling sites differ from season to season, both in quality and in quantity. The pollen counts of the various taxa differ, from site to site, in the time of maximum number of grains and in the quantity of airborne grains. Discussion of results is separate for each taxon.

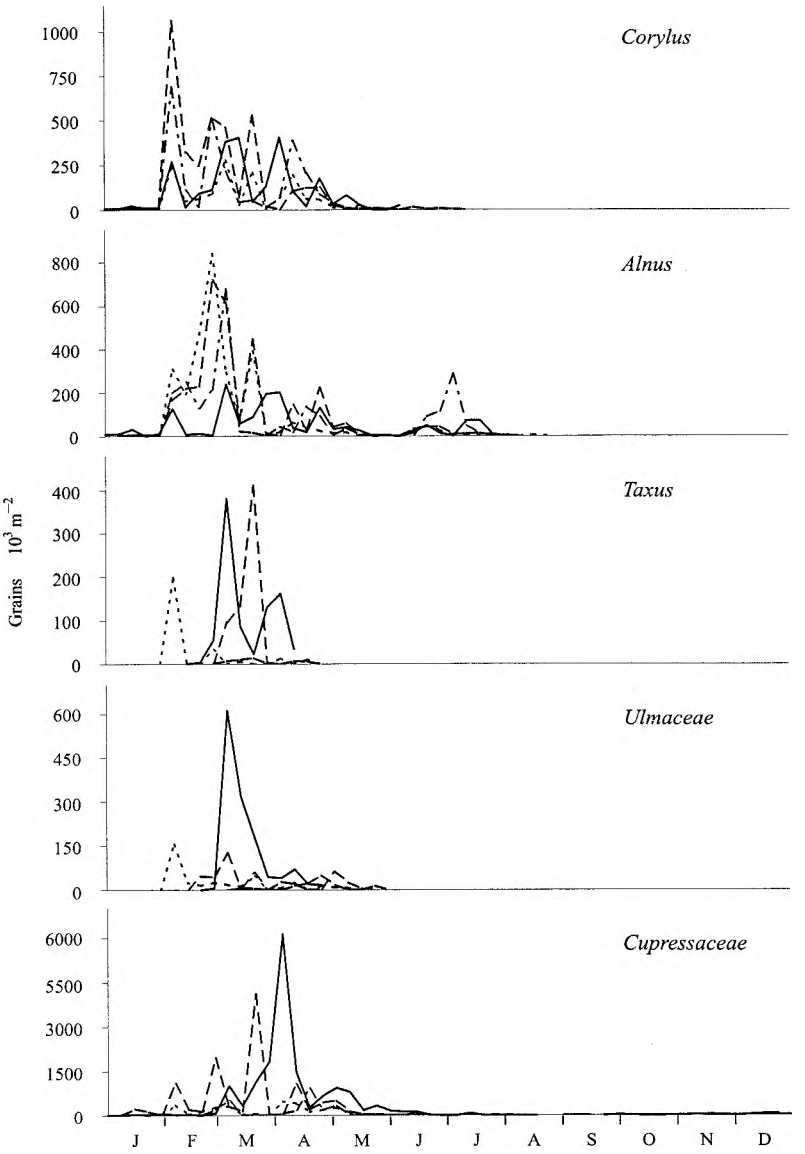

Fig. 2. Variation of the mean weekly pollen concentrations (Cour method) of the following types: *Corylus*, *Alnus*, *Taxus*, *Ulmaceae*, *Cupressaceae* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

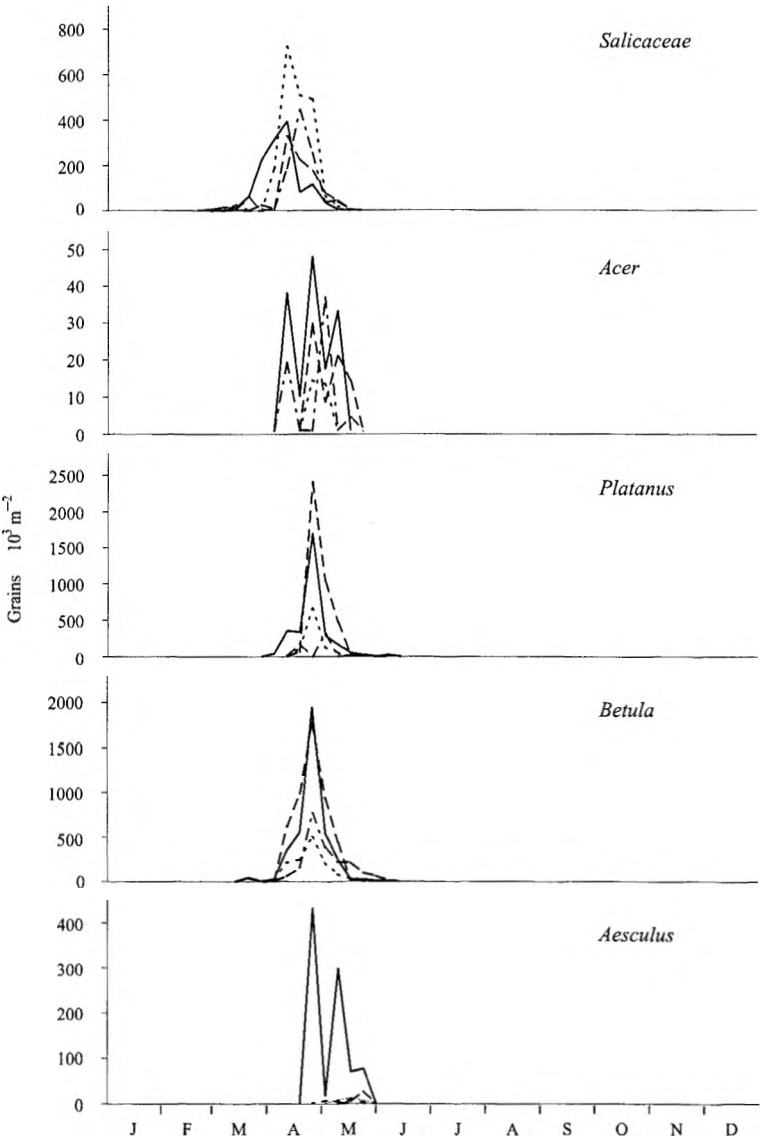

Fig. 3. Variation of the mean weekly pollen concentrations (Cour method) of the following types: *Salicaceae*, *Acer*, *Platanus*, *Betula*, *Aesculus* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

Acer

The pollen season of maples (Tab. 2) occurs in spring, from mid-April to mid-May (Fig. 3), reaching rather low pollen counts (Tab. 1). The pollination peak of *Acer* (Tab. 3) in Trieste reaches higher values than elsewhere (48×10^3 grains m^{-2}).

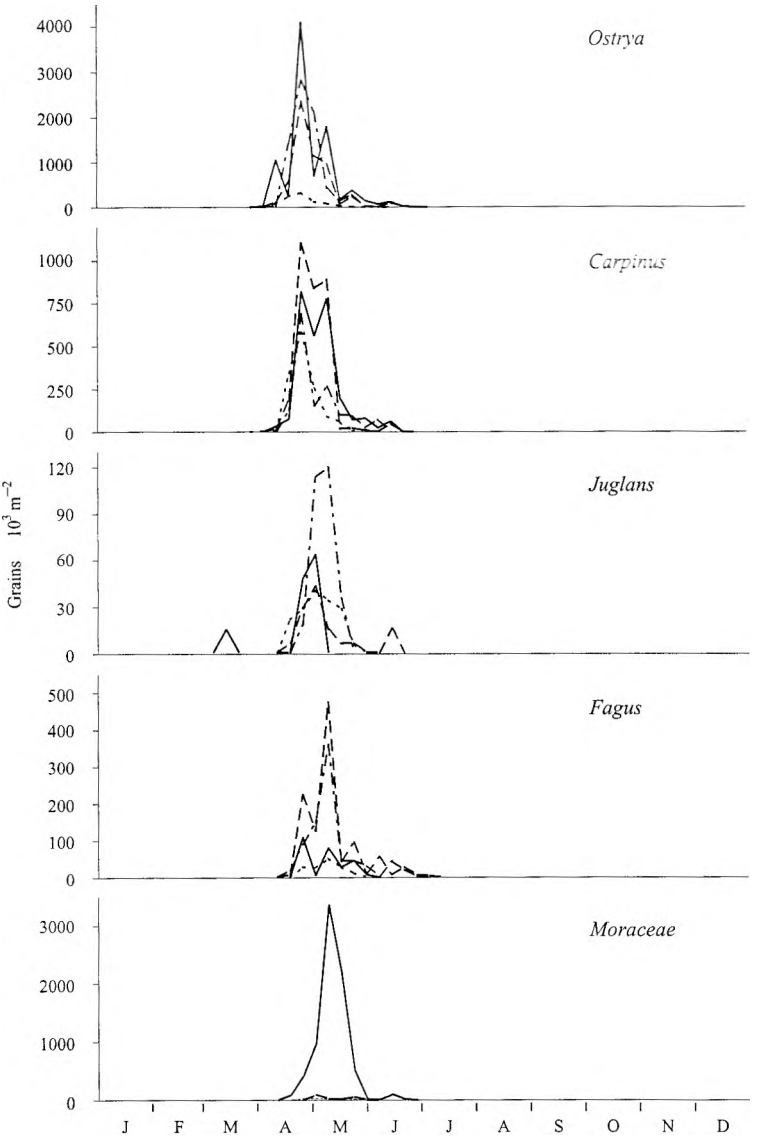

Fig. 4. Variation of the mean weekly pollen concentrations (Cour method) of the following types: *Ostrya*, *Carpinus*, *Juglans*, *Fagus*, *Moraceae* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

Aesculus

Pollen shedding of *Aesculus* is negligible in all sampling sites except Trieste (Fig. 3), where the pollen counts of these species reach very high values (Tab. 3). The high pollen counts recorded at the end of April (433×10^3 grains m^{-2}) are justified by the presence of horse chestnuts upwind and close to the spore traps.

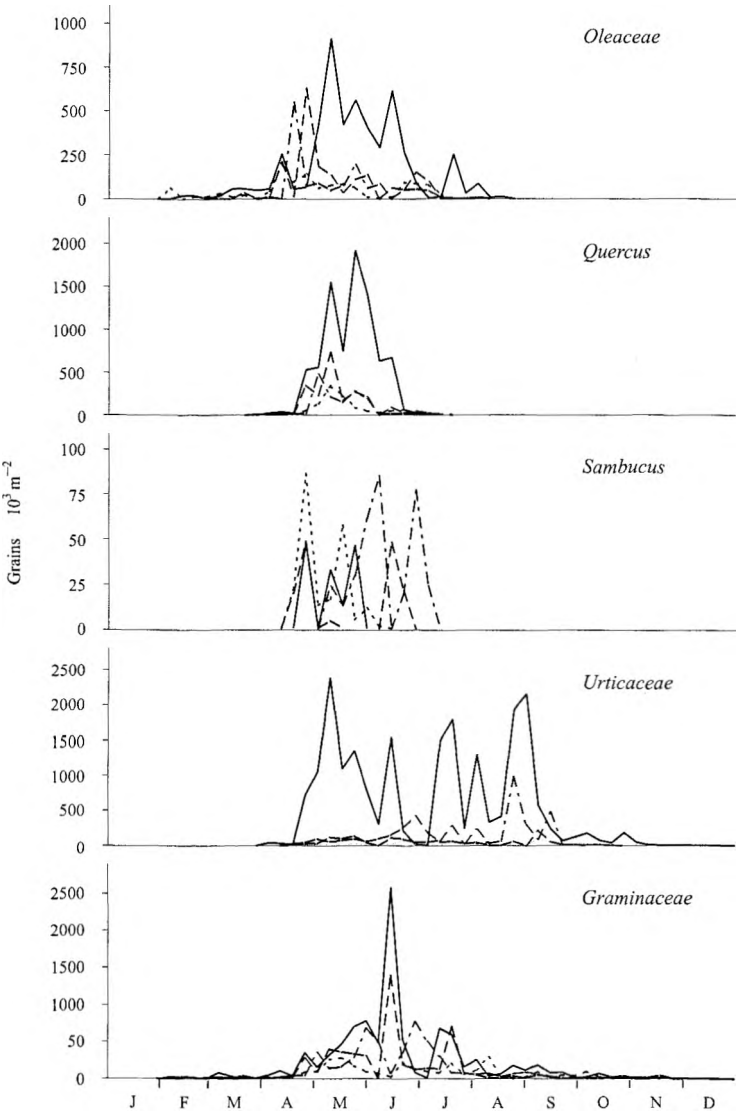

Fig. 5. Variation of the mean weekly pollen concentrations (Cour method) of the following types: *Oleaceae*, *Quercus*, *Sambucus*, *Urticaceae*, *Graminaceae* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

Alnus

Alnus pollen first appears in January (Fig. 2), but pollen counts of this species start increasing conspicuously in the first half of February (Tab. 2), reaching their maximum in mid-March (Tab. 3). Resuspended alder pollen grains may be commonly found in air samples until mid-May. *Alnus* pollen is rather rare in Trieste (max 240×10^3 grains m^{-2}), due to the small number of trees of this genus.

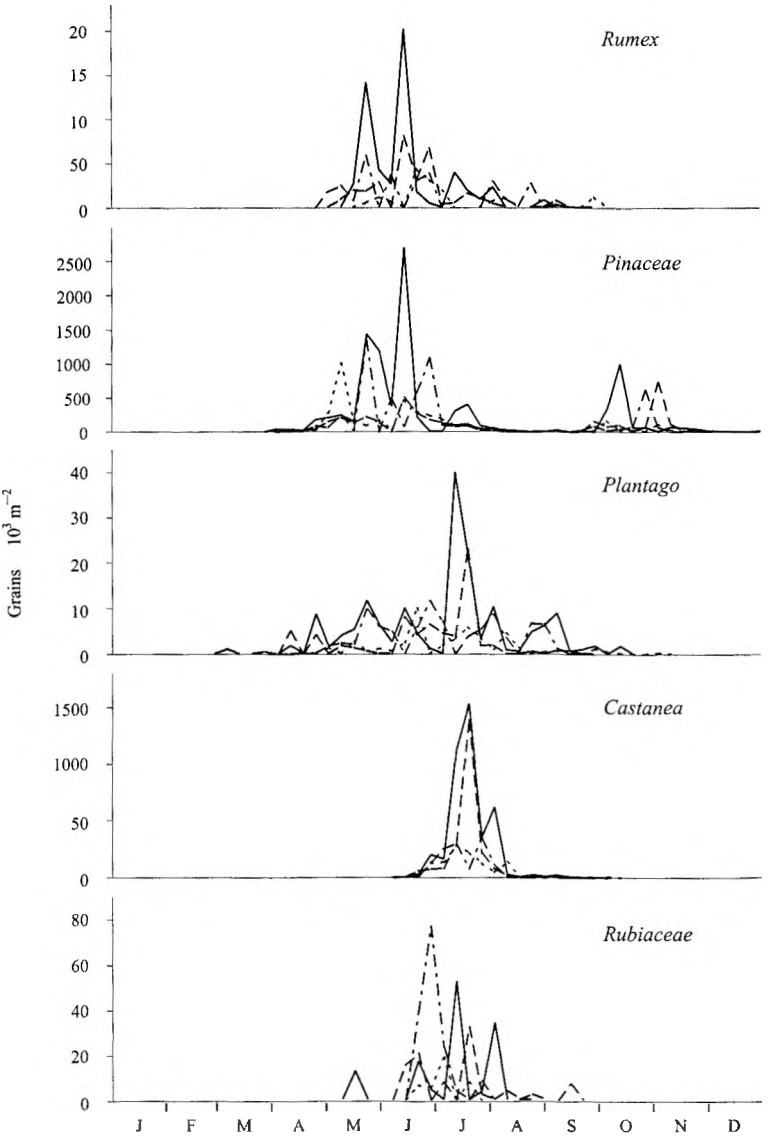

Fig. 6. Variation of the mean weekly pollen concentrations (Cour method) of the following herbaceous types: *Rumex*, *Pinaceae*, *Plantago*, *Castanea*, *Rubiaceae* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

Maximum pollen counts occur in Latisana (839×10^3 grains m^{-2}), where *Alnus glutinosa* is frequent, especially in the outskirts of the village. The presence of pollen grains in June and July, with particularly high counts in Tolmezzo, is due to *A. viridis* pollen, wind-borne from alpine scrubs.

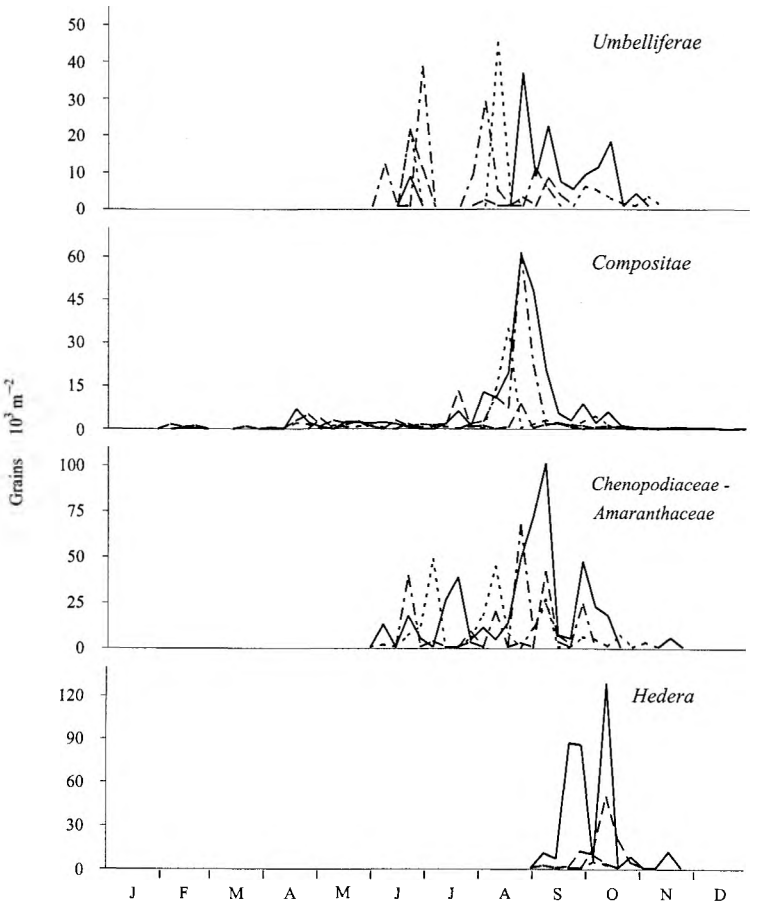

Fig. 7. Variation of the mean weekly pollen concentrations (Cour method) of the following herbaceous types: *Umbelliferae*, *Compositae*, *Chenopodiaceae-Amaranthaceae*, *Hedera* (— Trieste; – – – Udine;····· Latisana; – · – Tolmezzo).

Betula

The pollen season of *Betula* lasts only one month (Tab. 2), although *Betula* pollen grains may be found both just before and just after the main pollen season (Fig. 3). In all sampling sites, maximum pollen counts occur at the end of April (Tab. 3), with very high values in Trieste and Udine (1950×10^3 and 1778×10^3 grains m^{-2}, respectively). This is probably due to frequent cultivation of *Betula* species, in gardens, for ornamental purposes. In Tolmezzo and Latisana, pollen counts are much lower (772×10^3 and 502×10^3 grains m^{-2}, respectively).

Carpinus

Airborne *Carpinus* pollen may be found in air samples from mid-April until May (Fig. 4). Only *Carpinus betulus* pollen grains are included in this pollen type. *C. orientalis* pollen is included, because of its shape, in the *Ostrya* pollen

Tab. 1. Total annual sums ($N \times 10^3$ grains m^{-2}) and percentage presence of pollen types, during 1984, in the Friuli-Venezia Giulia sampling sites.

Locality	Trieste		Udine		Latisana		Tolmezzo	
Pollen type	total	%	total	%	total	%	total	%
Acer	149	0.12	76	0.12	29	0.09	66	0.13
Aesculus	898	0.74	32	0.05	19	0.06	34	0.07
Alnus	1540	1.27	3192	5.03	2866	9.68	2429	4.73
Betula	3761	3.10	4843	7.63	1311	4.43	1975	3.85
Carpinus	2697	2.22	3139	4.94	1296	4.38	1528	2.98
Castanea	5393	4.44	2409	3.79	1103	3.72	1081	2.11
Cheno.-Amaranth.	475	0.39	64	0.10	219	0.74	213	0.42
Compositae	2349	1.94	646	1.02	796	2.69	1246	2.43
Corylus	2496	2.06	3731	5.88	1396	4.71	2461	4.79
Cupressaceae	16251	13.39	11034	17.38	2794	9.43	2577	5.02
Fagus	282	0.23	1036	1.63	95	0.32	841	1.64
Graminaceae	9445	7.78	5034	7.93	2904	9.81	4877	9.51
Hedera	353	0.29	92	0.14	9	0.03	35	0.07
Juglans	132	0.11	129	0.20	162	0.55	291	0.57
Moraceae	7707	6.35	130	0.20	95	0.32	210	0.41
Oleaceae	5079	4.19	1758	2.77	1255	4.24	1754	3.42
Ostrya	8819	7.27	5625	8.86	907	3.06	7253	14.14
Pinaceae	9319	7.68	3535	5.57	3584	12.11	5222	10.18
Plantago	1634	1.35	707	1.11	457	1.54	902	1.76
Platanus	2971	2.45	4031	6.35	953	3.22	499	0.97
Quercus	8210	6.77	2169	3.42	1091	3.68	1394	2.72
Rubiaceae	136	0.11	92	0.14	44	0.15	175	0.34
Rumex	569	0.47	314	0.49	164	0.55	293	0.57
Salicaceae	1273	1.05	929	1.46	2029	6.85	956	1.86
Sambucus	145	0.12	148	0.23	219	0.74	338	0.66
Taxus	876	0.72	657	1.03	261	0.88	33	0.06
Ulmaceae	1303	1.07	383	0.60	356	1.21	154	0.31
Umbelliferae	139	0.11	58	0.09	97	0.33	118	0.23
Urticaceae	20901	17.22	1551	2.44	675	2.28	3807	7.42
Unidentified	6049	4.98	5942	9.36	2428	8.19	8542	16.65
Total	121351	100	63486	100	29614	100	51304	100

type. Maximum pollen concentrations (Tab. 3) occur in Udine (1101×10^3 grains m^{-2}), the minimum in Latisana (580×10^3 grains m^{-2}).

Castanea

The pollen season of *Castanea* occurs in July (Fig. 6). Pollen counts in Trieste and Udine have rather high peaks (Tab. 3) in the second half of July. The pollen count pattern in Latisana has low values (the maximum is 279×10^3 grains m^{-2}) although it is extended in time. Values recorded in Tolmezzo are a little higher (342×10^3 grains m^{-2}). Chestnut pollen is small and easily wind-borne, so that it may frequently be found in air samples even when the flowering season is over.

Tab. 2. Beginning and end of the main pollen season of the identified pollen types, during 1984, in the Friuli-Venezia Giulia sampling sites.

	Main Pollen Season							
Locality	Trieste		Udine		Latisana		Tolmezzo	
Taxon	Beginn.	End	Beginn.	End	Beginn.	End	Beginn.	End
Acer	9 Apr	13 May	23 Apr	20 May	23 Apr	6 May	9 Apr	20 May
Aesculus	23 Apr	27 May	7 May	27 May	23 Apr	27 May	14 May	27 May
Alnus	2 Feb	15 Jul	2 Feb	13 May	2 Feb	13 May	2 Feb	8 Jul
Betula	9 Apr	13 May	9 Apr	13 May	9 Apr	13 May	16 Apr	27 May
Carpinus	23 Apr	3 Jun	16 Apr	13 May	16 Apr	13 May	16 Apr	3 Jun
Castanea	2 Jul	5 Aug	25 Jun	29 Jul	25 Jun	12 Aug	18 Jun	5 Aug
Cheno.-Amaranth.	18 Jun	7 Oct	2 Jul	16 Sep	25 Jun	21 Oct	18 Jun	30 Sep
Compositae	14 May	7 Oct	26 Feb	23 Sep	7 May	7 Oct	21 May	9 Sep
Corylus	2 Feb	10 Jun	2 Feb	29 Apr	2 Feb	29 Apr	2 Feb	29 Apr
Cupressaceae	5 Mar	3 Jun	2 Feb	6 May	2 Feb	13 May	26 Feb	6 May
Fagus	23 Apr	3 Jun	23 Apr	17 Jun	23 Apr	27 May	23 Apr	17 Jun
Graminaceae	23 Apr	9 Sep	23 Apr	5 Aug	16 Apr	30 Sep	30 Apr	26 Aug
Hedera	10 Sep	28 Oct	1 Oct	28 Oct	24 Sep	21 Oct	3 Sep	21 Oct
Juglans	12 Mar	6 May	16 Apr	17 Jun	16 Apr	20 May	23 Apr	20 May
Moraceae	23 Apr	27 May	23 Apr	27 May	23 Apr	27 May	30 Apr	27 May
Oleaceae	9 Apr	22 Jul	9 Apr	1 Jul	12 Feb	8 Jul	16 Apr	8 Jul
Ostrya	9 Apr	27 May	16 Apr	27 May	9 Apr	13 May	16 Apr	20 May
Pinaceae	30 Apr	14 Oct	30 Apr	4 Nov	30 Apr	14 Oct	7 May	28 Oct
Plantago	23 Apr	9 Sep	9 Apr	5 Aug	7 May	30 Sep	14 May	2 Sep
Platanus	9 Apr	13 May	23 Apr	13 May	16 Apr	6 May	16 Apr	6 May
Quercus	23 Apr	17 Jun	23 Apr	17 Jun	23 Apr	24 Jun	30 Apr	3 Jun
Rubiaceae	14 May	5 Aug	11 Jun	19 Aug	18 Jun	22 Jul	18 Jun	9 Sep
Rumex	14 May	5 Aug	14 May	5 Aug	28 May	30 Sep	30 Apr	26 Aug
Salicaceae	19 Mar	29 Apr	19 Mar	6 May	2 Apr	29 Apr	9 Apr	29 Apr
Sambucus	23 Apr	27 May	16 Apr	24 Jun	16 Apr	3 Jun	7 May	8 Jul
Taxus	26 Feb	8 Apr	5 Mar	25 Mar	2 Feb	8 Apr	5 Mar	25 Mar
Ulmaceae	5 Mar	15 Apr	19 Feb	29 Apr	2 Feb	29 Apr	19 Mar	6 May
Umbelliferae	18 Jun	14 Oct	18 Jun	16 Sep	18 Jun	28 Oct	4 Jun	9 Sep
Urticaceae	30 Apr	9 Sep	30 Apr	9 Sep	21 May	7 Oct	21 May	16 Sep

Chenopodiaceae - Amaranthaceae

Species belonging to *Chenopodiaceae* and *Amaranthaceae* have very similar pollen grains, which are usually included in the same pollen type. The pollen season extends from June to October (Tab. 2), with maximum pollen counts (Tab. 3) between August and September, and many local peaks (Fig. 7). The highest values are recorded in Trieste (101×10^3 grains m^{-2}) and in Tolmezzo (68×10^3 grains m^{-2}). In Latisana and Udine, pollen counts of these species are rather low, the maxima being 49×10^3 and 42×10^3 grains m^{-2}, respectively. In all examined sites this pollen type contributes only marginally to the total pollen counts (Tab. 1).

Tab. 3. Week in which the pollination peak occurs, and maximum concentration of the identified pollen types, during 1984, in the Friuli-Venezia Giulia sampling sites.

	Maximum concentration							
Locality	Trieste		Udine		Latisana		Tolmezzo	
Taxon	Week	10^3 grains/m^2	Week	10^3 grains/m^2	Week	10^3 grains/m^2	Week	10^3 grains/m^2
Acer	17	48	17	30	17	14	18	37
Aesculus	17	433	20	13	18	7	21	28
Alnus	10	240	9	720	9	839	10	676
Betula	17	1950	17	1778	17	502	17	772
Carpinus	17	818	17	1101	17	580	17	688
Castanea	29	1529	29	1386	28	279	30	342
Cheno.-Amaranth.	36	101	36	42	27	49	34	68
Compositae	34	608	28	131	33	346	34	612
Corylus	11	403	6	1062	10	278	6	687
Cupressaceae	14	6122	12	4107	14	479	16	918
Fagus	16	110	19	475	17	29	19	360
Graminaceae	24	2586	24	1397	20	288	26	771
Hedera	41	129	41	50	40	5	39	13
Juglans	18	64	18	43	18	40	19	120
Moraceae	19	3364	20	33	17	30	18	98
Oleaceae	19	913	17	626	15	187	16	548
Ostrya	17	4102	17	2352	17	322	17	2816
Pinaceae	24	2686	44	728	19	1004	21	1340
Plantago	28	399	29	231	25	101	26	116
Platanus	17	1698	17	2404	17	663	18	313
Quercus	21	1924	19	733	19	339	18	478
Rubiaceae	28	53	29	33	27	20	26	77
Rumex	24	201	24	80	25	43	21	59
Salicaceae	15	396	15	328	15	724	16	445
Sambucus	17	48	17	49	17	86	23	85
Taxus	9	380	12	411	6	198	12	14
Ulmaceae	10	612	10	125	6	154	18	64
Umbelliferae	34	37	25	21	32	45	26	39
Urticaceae	19	2392	29	211	36	93	34	988

Compositae

Very few pollen grains of these species are usually found in air samples from February to October (Fig. 7). Because of their entomophilous pollination, pollen counts of these species are always very low (Tab. 1), even at the time of maximum flowering, from April onwards. Only towards the end of summer pollen counts sharply increase (Tab. 3), when the anthesis of anemophilous species begins. From the beginning of August to October, the pollen shedding of *Compositae* species is almost entirely due to *Artemisia* pollens. Pollen counts of *Artemisia* are quite high in Tolmezzo and Trieste, with maxima of 601×10^3 and 496×10^3 grains m^{-2}, respectively, in the third week of August. Maximum pollen counts in

Latisana are lower (337×10^3 grains m^{-2}), and occur in mid-August, while the pollen shedding of *Artemisia* in Udine is very low (max.= 77×10^3 grains m^{-2}). Finally, pollen grains of *Ambrosia* are also found from August to mid-September, especially in Trieste, although their presence is almost negligible: maximum is 23×10^3 grains m^{-2}, at the end of August.

Corylus

The pollen curve of *Corylus* is rather extended and complex (Fig. 2). Hazel pollen may be found in high amounts from the first week of February to the end of April (Tab. 2). During these months, pollen counts record various increases and decreases, due to hazels flowering at different times in different microclimates (RIZZI LONGO and PIZZULIN SAULI 1998), or to meteorological events. The highest concentrations of airborne *Corylus* pollen occur in Udine and Tolmezzo. Pollen counts reach their maximum quite early, at the beginning of February, reaching 1062×10^3 grains m^{-2} in Udine and 687×10^3 grains m^{-2} in Tolmezzo (Tab. 3). Lower peaks occur in Trieste and Latisana (403×10^3 and 278×10^3 grains m^{-2}, respectively), around mid-March. Any later presence of this pollen is due to wind-borne or resuspended grains.

Cupressaceae

The pollen count pattern of *Cupressaceae* species is rather complex and it covers a very long period of time (Fig. 2). Pollen grains of these species may be found throughout the year, although the highest concentrations are recorded during winter and spring. The pollen counts of each sampling site reach various successive peaks. These are particularly high in Trieste and Udine, where maximum pollen counts (Tab. 3) are recorded at the beginning of April (6122×10^3 grains m^{-2}) and in the second half of March (4107×10^3 grains m^{-2}), respectively. The exceptional values recorded in Trieste are not only due to a higher number of cypresses compared to the other sampling sites, but mostly to their abundance around San Giusto Castle, where the spore trap was placed. In Latisana and Tolmezzo, pollen counts are very smaller (479×10^3 and 918×10^3 grains m^{-2}, respectively). Finally, the presence of *Cupressaceae* pollen until June, particularly in Trieste and Tolmezzo, is due to the late flowering of junipers.

Fagus

Although beech woods are quite frequent in the montane zone, *Fagus* pollen is found in small amounts in air samples (Tab. 1), from the end of April to mid-May; later on, the presence of this pollen is only occasional (Fig. 4). Maximum pollen counts (Tab. 3) occur in Udine and Tolmezzo, in the second week of May (475×10^3 and 360×10^3 grains m^{-2}, respectively). Pollen counts are extremely low in Trieste and almost negligible in Latisana, due to the near absence of beeches and the low transportability of these pollen grains.

Graminaceae

The pollen shedding of *Graminaceae* species is quite long, going on from February to November, and complex, because of the successive flowering of

many species (Fig. 5). The possible presence of *Graminaceae* pollens in December and January is seemingly due to resuspended grains. The pollen season is most intense from the end of April to September (Tab. 2), with pollination peaks between mid-May and mid-July. Pollen counts in Trieste and Udine are similar in the pattern of the pollen counts, and in the time of maximum counts (mid-June), even though the maximum in Trieste (2586×10^3 grains m^{-2}) is higher than in Udine (1397×10^3 grains m^{-2}) and pollen shedding is longer in the former sampling site. The higher values recorded in March and April are due to early flowering species (*Sesleria juncifolia* and *Poa annua*, among others), while the higher values recorded from August onward are due to the late anthesis of long-day species (*Bothriochloa ischaemum* and *Digitaria sanguinalis*, among others). In Tolmezzo as well, the pollen shedding of *Graminaceae* species is abundant, even if with lower values. Maximum pollen counts (771×10^3 grains m^{-2}) occur at the end of June (Tab. 3). Latisana air samples have the lowest concentration of *Graminaceae* pollens, with a maximum of only 288×10^3 grains m^{-2} in mid-May.

Hedera

The late pollen shedding of *Hedera helix* (from mid-September to mid-October) is uneven between the sampling sites (Fig. 7): it is scarce in Tolmezzo and Latisana, while it is rather high in Udine (50×10^3 grains m^{-2}) and abundant in Trieste (129×10^3 grains m^{-2}), mostly because of the fact that this species amply covers the walls of San Giusto Castle.

Juglans

The pollination curve of *Juglans* starts at the end of April and ends in late March (Fig. 4). Maximum pollen counts (Tab. 3) occur in the first week of May in Trieste (64×10^3 grains m^{-2}), Udine (43×10^3 grains m^{-2}) and Latisana (40×10^3 grains m^{-2}). In Tolmezzo, pollen shedding occurs later on and with higher pollen counts: the peak concentration reaches 120×10^3 grains m^{-2} in the second week of May. In all examined sites this pollen type contributes only marginally to the total pollen counts (Tab. 1).

Moraceae

Pollen grains of *Moraceae* species may be found in very small quantities in Udine, Tolmezzo and Latisana (Tab. 1), while they are abundant in Trieste air samples (Fig. 4), from the end of April to the end of May (Tab. 2), with a maximum of 3364×10^3 grains m^{-2} in the second week of May (Tab. 3). These grains consist mostly of *Broussonetia papyrifera*, an exotic species introduced in the past, which now infests non-cultivated land, frequent on road-sides in the outskirts of town and in other abandoned public areas of town and its surroundings.

Oleaceae

This family has an interesting and information-rich pollen count pattern (Fig. 5). *Oleaceae* pollens are mainly ash, olive tree and privet pollen, easily identified and recorded in all sites; other pollen types included in these pollen counts, al-

though in minimal amounts, are *Phillyrea angustifolia*, and other *Oleaceae* species cultivated for ornamental purposes, such as *Jasminum nudiflorum*, *Forsythia viridissima* and *Syringa vulgaris*. The pollination curve starts, with low pollen counts, at the beginning of February, with the pollen shedding of *Jasminum*; the pollen shedding of *Forsythia* follows, again, with low pollen counts. At the beginning of April there is a sharp increase of pollen counts, which corresponds to the pollen shedding of various *Fraxinus* species (*F. oxycarpa*, *F. excelsior* and, later on, *F. ornus*), which determine the pollen count peaks. Maximum pollen concentrations (Tab. 3) are recorded at different times, in the different sampling sites; in Latisana, maximum pollen counts (187×10^3 grains m^{-2}) occur in mid-April; in Tolmezzo (548×10^3 grains m^{-2}), a week later; in Udine (626×10^3 grains m^{-2}) at the end of April; in Trieste (913×10^3 grains m^{-2}) in the second week of May. In the first three sampling sites, pollen counts decrease rapidly at the beginning of May, successively reaching low local maxima; the pollen season ends at the beginning of July. In Trieste, on the contrary, pollen counts remain quite high throughout May, because of the extensive pollen shedding of the flowering ash, frequent in the natural vegetation of the Karst and of the marl hills surrounding the urban area. The pollen shedding of *Phillyrea* also contributes to the pollen counts; species of this genus may be found in the relict Mediterranean »macchia« of Trieste's seaboard. The increase in pollen counts in mid-June is due to the pollen shedding of *Olea europaea*, frequently cultivated in the countryside south-east of town, and to the pollen shedding of *Ligustrum vulgare*, which grows in natural vegetation formations. The further increase in pollen counts that occurs in July is due to the late flowering of *Ligustrum lucidum*, frequently cultivated for ornamental purposes.

Ostrya

Ostrya pollen is found in air samples in high concentrations from mid-April to mid-May (Fig. 4). Pollen may also be found later on, until mid-June, probably resulting from wind-borne and/or resuspended grains. Maximum pollen counts (Tab. 3) occur at the end of April in all sampling sites. Exceptionally high pollen counts are recorded in Trieste, for a longer period: the pollen count reaches local maxima in mid-April (1051×10^3 grains m^{-2}) and mid-May (1801×10^3 grains m^{-2}), while the absolute maximum (4102×10^3 grains m^{-2}) is recorded at the end of April. In Tolmezzo and Udine, as well, maximum pollen counts reach rather high values (2816×10^3 and 2352×10^3 grains m^{-2}, respectively), but the pollen curve covers a shorter period. In Latisana, on the contrary, the concentration of airborne hop hornbeam pollen is quite small, with a maximum of 322×10^3 grains m^{-2}, due to the small number of nearby sources.

Pinaceae

The pollen count pattern of *Pinaceae* species is also quite complex and extended in time (Fig. 6). In Latisana maximum pollen counts (1004×10^3 grains m^{-2}) occur quite early (mid-May); in Tolmezzo the pollen count peak (1340×10^3 grains m^{-2}) occurs at the end of May, while in Trieste maximum pollen counts occur in mid-June (2686×10^3 grains m^{-2}) and in Udine at the end of

October (728×10^3 grains m^{-2}). The pollen grains of various species of *Abies*, *Cedrus*, *Larix*, *Picea* and *Pinus* genera contribute to the pollen counts. *Pinus* pollen grains are extremely abundant in the spring pollen season, from the end of April to July. In fact, the various pollen count peaks recorded in this season are mostly due to species of this genus, both spontaneous and cultivated, which flower in succession and whose pollen grains are easily carried by the wind. Pollen grains of the other *Pinaceae* taxa are found in much lower concentrations, in all the sampling sites. Pollen grains of the silver fir, of the spruce and of the larch contribute only marginally to the total *Pinaceae* pollen counts, because of their dimensions and weight. The *Abies* pollen season is very short, from the end of May to the end of June, and maximum pollen counts are rather low: 70×10^3 grains m^{-2} in Trieste, 77 in Tolmezzo, and they are lower still in Udine and Latisana. *Larix* pollen grains are found in air samples only occasionally in the first half of May, with low peaks: 16×10^3 grains m^{-2} in Trieste, 26 in Udine and 51 in Tolmezzo. *Picea* pollen season is longer, from the end of April to the end of June, with maxima of 213×10^3 grains m^{-2} in Trieste, 149 in Udine, 501 in Tolmezzo, and 122 in Latisana. On the other hand, *Cedrus* pollen grains are abundant, and the main contributors to the autumn pollen season. In Trieste the pollen counts of these species are particularly high, with a maximum of 1000×10^3 grains m^{-2} at the beginning of October. This abundance is certainly due to the high number of cedars growing in the »Parco della Rimembranza«, which is just under the walls of San Giusto Castle. *Cedrus* pollen is less abundant in Tolmezzo and Udine, and the maximum pollen counts are recorded later on. The concentrations found in Latisana are extremely low.

Plantago

The pollination curve of *Plantago* starts at the beginning of March and ends in mid-October (Fig. 6). Maximum pollen counts occur between the end of April and the end of August, and increases and decreases in the counts are frequent. The peak of pollen counts (Tab. 3) is isolated, in mid-July, in Trieste (399×10^3 grains m^{-2}) and Udine (231×10^3 grains m^{-2}). In Latisana and Tolmezzo the pollen counts for *Plantago* are lower (maximum 101 and 116×10^3 grains m^{-2}, respectively).

Platanaceae

The *Platanus* pollen season is short but intense (Fig. 3). High quantities of airborne pollen are found in all sampling sites from the end of April to mid-May (Tab. 2). Pollen peaks occur in most sampling sites at the end of April (Tab. 3), but with different pollen counts (2404×10^3 grains m^{-2} in Udine, 1698 in Trieste and 663 in Latisana). In Tolmezzo pollen counts are low (max 313×10^3 grains m^{-2}) and pollen shedding occurs later on.

Quercus

Oak pollen shedding differs significantly in the various sampling sites, although it is more or less synchronous (Fig. 5). Pollen grains may be found in samples mainly from the end of April to the beginning of June. *Quercus* pollen

grains in Trieste are superabundant and they may be found in samples for a rather long period; moreover, pollen counts record various peaks. These are due in part to broad-leaved oaks flowering in succession (*Quercus robur*, *Q. pubescens* and *Q. cerris*), which are quite frequent in the natural vegetation of the Karst and of the sandstone hills that encircle the town. The maximum peak (Tab. 3) occurs in May (1924×10^3 grains m^{-2}). The increase in pollen counts in the first half of June is due to the late anthesis of *Quercus ilex*, spontaneous in the relict Mediterranean »macchia« of Trieste's seaboard, and cultivated to line some of the town's avenues. The pollen count patterns of the other regional sampling sites are simpler and cover a shorter period; the maximum pollen counts (Tab. 3) occur somewhat earlier, with values quite a lot lower (733×10^3 grains m^{-2} in Udine, 478 in Tolmezzo and 339 in Latisana).

Rubiaceae

Airborne pollen of *Rubiaceae* species contribute only marginally to the total pollen counts (Tab. 1). The pollen shedding occurs during summer (Fig. 6), with maximum pollen counts (Tab. 3) at the end of June in Tolmezzo (77×10^3 grains m^{-2}), and in July in Latisana (20×10^3 grains m^{-2}), Trieste (53×10^3 grains m^{-2}) and Udine (33×10^3 grains m^{-2}).

Rumex

Rumex pollen grains (Fig. 6) are rather scarce in the air samples (Tab. 1). The main pollen season goes from May to August (Tab. 2). In Trieste, pollen shedding is conspicuous and early, with maximum pollen counts reaching 201×10^3 grains m^{-2} in mid-June (Tab. 3). In Udine, Latisana and Tolmezzo, pollen shedding is scarcer, with peaks reaching 80, 43 and 59×10^3 grains m^{-2}, respectively, in mid-late June (Tab. 3); pollen shedding then decreases, increasing again at the end of July and lasting until the beginning of September.

Salicaceae

The pollen season of *Salicaceae* species is quite short (Tab. 2), but with low counts, despite the fact that willows and poplars are quite frequent in the study area. *Populus* pollen grains are responsible for the first part of the pollen curve (Fig. 3), which includes the highest values of the pollen counts. The pollination curve starts in Trieste earlier than in the other sampling sites, although the peaks are reached simultaneously in mid-April (Tab. 3), except for Tolmezzo, where the peak occurs a week later. The peak values are 724×10^3 grains m^{-2} in Latisana, 396 in Trieste, 328 in Udine and 445 in Tolmezzo. Salix pollen contribution is conspicuous only in Latisana, with peaks up to 454×10^3 grains m^{-2} in the third week of April. In the other sampling sites pollen counts for this genus are rather low, with peaks lower than 250×10^3 grains m^{-2}, in the maximum pollen shedding period, at the end of April.

Sambucus

Sambucus airborne pollen grains are not frequent in the sampling sites (Tab. 1). The pollination curve (Fig. 5) starts at the end of April and ends quite early, by

the end May, in Latisana and Trieste, while it until late June in Udine and Tolmezzo. Maximum pollen counts (Tab. 3) are higher in Latisana and Tolmezzo (86 and 85×10^3 grains m^{-2}, respectively), and rather low in Trieste and Udine (48 and 49×10^3 grains m^{-2}, respectively).

Taxus

It is very difficult to distinguish *Taxus* pollen grains from those of *Cupressaceae* species, so that they are usually counted together. *Taxus* pollen grains identified with certainty (Fig. 2) are found in rather high concentrations in March. The peaks reach 380×10^3 grains m^{-2} in Trieste, 411 in Udine and 198 in Latisana (Tab. 3).

Ulmaceae

The pollination curve of *Ulmaceae* starts in mid-February and lasts until the end of March (Fig. 2). Later presence of this pollen is due to wind-borne or resuspended grains. The most frequent pollen grains found are those of *Ulmus* species, which flower quite early and are very frequent even in urban areas. Pollen counts of *Celtis australis*, which flowers later on, are very low. On the whole, *Ulmaceae* pollen shedding is rather low (Tab. 1), with the exception of Trieste, where pollen counts are as high as 612×10^3 grains m^{-2} in the second week of March (Tab. 3).

Umbelliferae

Although pollens of *Umbelliferae* are rather infrequent in air samples (Tab. 1), the pattern of pollen counts is quite interesting (Fig. 7). There are two periods of pollen shedding, one in late spring (June), and another in late summer (August-October), due to the different flowering periods of various species. Peaks in pollen counts (Tab. 3) occur at the end of June in Udine and Tolmezzo (21 and 39×10^3 grains m^{-2}), while in Latisana and Trieste maximum pollen counts occur in mid-August (45 and 37×10^3 grains m^{-2}, respectively).

Urticaceae

The pollination curve of *Urticaceae* is quite different between the four sampling sites (Fig. 5). In Trieste, this taxon accounts for the relative majority of total airborne pollens (Tab. 1). Except for a few brief periods, from the end of April to mid-September, pollen counts are much higher than any of the pollen peaks in the other sites. Two main peaks are well isolated, one in mid-May (2392×10^3 grains m^{-2}) and the other at the end of August (2164×10^3 grains m^{-2}), which are mostly due, like the rest of the pollen counts, to *Parietaria* pollen grains, frequent in the area and abundant on the walls both of San Giusto Castle and of the old part of town, which lies at the foot of the Hill of San Giusto. Among the other sampling sites, in Tolmezzo, *Urticaceae* pollens are particularly abundant, with a peak of 988×10^3 grains m^{-2} in the third week of August (Tab. 3). In Udine and Latisana, pollen counts are rather low, reaching peaks of 211 and only 93×10^3 grains m^{-2}, respectively.

Other taxa

Apart from the arboreal taxa above mentioned, other tree and shrub pollen frequently found, although in extremely low quantities, are *Buxus* (March-April), *Tamarix* and *Rosaceae* (April-May), *Robinia pseudacacia* (May), *Vitis* and *Ailanthus* (June), and *Tilia* (June-July). Occasionally, *Acacia*, *Viburnum*, *Myrtus*, *Cornus* and *Parthenocissus* have also been found.

Among the herbaceous taxa whose pollen grains have been recorded in the sampling sites, many others may be found in air samples. Among others, *Ericaceae*, *Mercurialis*, *Carex*, *Cruciferae* and *Symphytum* are rather frequent in spring, *Liliaceae* and *Caryophyllaceae* may be found both in spring and in late summer, while *Typha*, *Valeriana* and *Humulus* are typically found in summer.

Discussion

Airborne pollens captured in 1984 are rather diverse in the four sampling sites, both in quantity and duration of pollen shedding, and in the contribution of the different taxa. Only *Betula* pollen count patterns are similar, although they differ in quantity.

Trieste is quite different from the other sampling sites, both for the higher values of overall pollen counts and for the superabundant pollen shedding of *Cupressaceae*, *Ulmaceae*, *Ostrya*, *Quercus*, *Moraceae*, *Oleaceae*, *Pinus*, *Castanea*, *Graminaceae*, *Urticaceae*, and other minor taxa. The particular features of airborne pollen counts in Trieste may be explained in part by the proximity of pollen sources to the spore trap, and in part by the floristic and vegetational richness of the area. Moreover, it must not be overlooked that pollen is also carried, by dominant winds, from nearby Slovenia. This fact is proved by the lengthened pollen season of spring flowering taxa.

Udine proves often similar to Trieste, although the sites have different pollen count values, in the patterns of some taxa, especially *Cupressaceae*, *Ostrya*, *Carpinus*, *Platanus*, *Quercus*, *Castanea*, and *Graminaceae*. The sampling site is characterised by more intense pollen shedding by *Corylus*, *Carpinus*, *Platanus*, and *Fagus*. On the other hand, the pollen counts for *Artemisia* are almost negligible, while those for *Urticaceae* are very low.

Latisana is characterised by the particular abundance of *Alnus* and *Salicaceae* pollens, and for the overall low pollen counts. In fact, nearly all the major taxa reach their minimum pollen counts at this site.

Tolmezzo is quite different from the other sampling sites. The main differences are in the patterns of the pollen counts for the considered taxa, and in the time of maximum counts. The concentrations of airborne pollens are often similar to those recorded in Udine. Exceptions are *Platanus* pollen, whose counts reach their minimum at this site, and *Juglans*, *Picea*, *Larix*, and *Abies* pollens, whose counts reach their maximum. *Urticaceae*, *Chenopodiaceae*, *Rubiaceae*, and *Artemisia* pollen counts reach their highest values in Tolmezzo, excluding Trieste. The total pollen count pattern is also different; the isolated peak between April and May, which occurs at the other sites, is missing; instead, the pollen counts maintain lower, but still rather high values, until the beginning of summer.

Total pollen counts of the four sampling sites are rather differentiated throughout the year and among the sites. The higher peaks in pollen counts are concentrated in spring, when most of the species growing in the study area flower. Airborne pollen grains are nonetheless abundant both in late winter-early spring and during the summer; pollen counts are negligible, or nearly so, only in late autumn and January. Peaks recorded in February and March are mostly due to the pollen shedding of *Cupressaceae*, along with *Corylus* and *Alnus*. In spring, the main pollen-shedding species are *Betula*, *Ostrya*, *Carpinus* and *Platanus*, at the end of April, *Fagaceae*, *Oleaceae*, *Urticaceae* and *Broussonetia* (especially in Trieste) in May, Pinaceae and Graminaceae in June. Summer is characterised by lower total pollen counts, which are mainly due to *Urticaceae* pollens, and to which *Castanea* pollen, in July, and *Artemisia* pollen, at the end of August, must be added. The autumn pollen season is mainly due to *Cedrus* pollen. *Acer*, *Aesculus*, *Chenopodiaceae-Amaranthaceae*, *Hedera*, *Juglans*, *Rubiaceae*, *Rumex*, *Sambucus*, *Taxus*, *Ulmaceae*, *Umbelliferae* pollen types contribute almost negligibly to total airborne pollen.

The most frequent pollen types, in all the study area, are those of the natural vegetation taxa, both arboreal and herbaceous, that grow on the territory. Thermophilous taxa are abundant in Trieste, while mesophilous taxa are more frequent in Udine. The low pollen counts of Latisana may be explained by the distance of the site from natural vegetation. In all sampling sites, the contribution to airborne pollens by anthropogenic vegetation is considerable, mostly by plants cultivated for ornamental purposes and by ruderal species.

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