

Original Paper

Aerobiology of Fagaceae pollen in Trieste (NE Italy)

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Abstract

The aerobiological behaviour of Fagaceae in Trieste and the correlations with the meteorological parameters were examined. Airborne pollen grains of *Castanea*, *Fagus* and *Quercus* were collected from 1990 to 2003 using a Hirst type spore trap. The main pollen season (MPS) takes place in April and May for *Quercus* and *Fagus*, in June and July for *Castanea*. The highest values occur in year 1993 for *Quercus*, in 1998 for *Castanea* and in 1992 for *Fagus*. The Fagaceae content of the air is mainly due to *Quercus* and *Castanea* pollen, *Fagus* usually having a scarce pollen shedding in Trieste. The highest counts of Fagaceae pollen grains are found from late April to mid May and are mainly due to the pollen shedding of oaks. The cumulative counts vary over the years, with a mean value of 2.719 pollen grains, a lowest total of 1.341 in 2002 and a highest total of 4.704 in 1993. No positive nor negative long-term trends in pollen shedding are found. No cyclic variations were observed. Spearman's correlation was used to establish the relationship between the daily pollen counts and the daily meteorological data. Daily pollen concentrations present sometimes positive correlation with temperature, negative with rainfall and wind speed, and no correlation with humidity. *Fagus* and *Quercus* start dates result positively correlated between themselves. Significant correlations are found between the start of MPS and the mean and maximum temperature in March for *Fagus* and *Quercus*, and May for *Castanea*.

1. Introduction

Plant genera belonging to Fagales are widespread in the temperate zone of the northern hemisphere. Their pollen grains occur in spring/summer samples in various European sites (Spieksma, 1991); they are the main source of allergens from trees during spring time (D'Amato, 2001). Cross-sensitivity is frequent within the Fagales: subjects who are positive to *Betula* have positive reactions to other genera of Betulaceae, and to Corylaceae and Fagaceae (Dalen and Voorhorst, 1981; Matthiesen et al., 1991). The genera of Fagaceae play, nevertheless, only a supporting part in inducing pollinosis in Europe: only when airborne pollen grains are abundant, *Castanea* (chestnut),

Fagus (beech) and *Quercus* (oak) could be responsible for allergic manifestations (Ickovic and Thibaudon, 1991). In Trieste, few people are monosensitive to Fagaceae; symptoms (mainly rhinitis) are related to the main pollen season, when daily airborne pollen counts become higher than 15–20 pollen grains per cubic meter of air (Larese et al., 1992). Fagaceae family has a high importance from an ecological, forestry and economical point of view. Airborne Fagaceae pollen behaviour and its relationship with climate has a great interest for aerobiology and forestry sciences. The fluctuation in the annual totals over several years and the behaviour of the pollen seasons, with regard to meteorological parameters, were studied for some sites and/or genera

(Corden and Millington, 1999; Iglesias et al., 1999; Detandt and Nolard, 2000; Frei and Leuschner, 2000; Moreno-Grau et al., 2000; Rodríguez-Rajo et al., 2000; Jato et al., 2001). Models to predict the start of the pollen season have also been proposed for *Castanea* (Mandrioli et al., 1993) and *Quercus* (Norris-Hill, 1998; García-Mozo et al., 2000; Rodríguez-Rajo et al., 2003).

In the Friuli-Venezia Giulia region, the following species of Fagaceae are present: *Castanea sativa* Mill., *Fagus sylvatica* L., *Quercus cerris* L., *Q. ilex* L., *Q. petraea* Liebl., *Q. pubescens* Willd., *Q. robur* L., *Q. rubra* L. and *Q. tommasinii* Kotschy (Poldini, 1991, 2002). *Castanea* requires more or less deep and acid or sub-acid soils. In all the coenoses in which chestnut grows in the north-eastern Adriatic territories, from the acidophilous oak wood to the sub-montane acidophilous beech forest, it seems not to be spontaneous. Re-introduced starting from the Sub-Atlantic (Poldini and Rizzi Longo, 2004), it belongs to archeophytes (Poldini et al., 2001). *Fagus* and *Quercus* are the main forest genera of the region, forming different natural woodland, oak woods in plain- and hill-belt vegetation series, and beech woods in the montane-belt. The beech forests are the most frequent type of forest in the south-eastern Alps, not far from Trieste (Poldini and Nardini, 1993).

Trieste stands at the north-eastern extremity of the Adriatic Sea, a zone of phyto-climatic boundary between the Mediterranean and Euro-Siberian regions, on a limited area between the coast and the Karst Plateau, that encircles the town north and east. Natural woody coenoses, mainly oak woods, are frequent in the Trieste area (Poldini, 1989). A thermophilous oak wood, the *Seslerio autumnalis-Quercetum petraeae*, covers in part the flysch hills surrounding the town. The “bosaglia carsica”, *Ostryo-Quercetum pubescentis*, prevails on the Karst Plateau and is common on the limestone slopes near the town. A sclerophyll oak wood, the *Ostryo-Quercetum ilicis*, survives as relict vegetation along the Costiera Triestina, a narrow coastal strip of steep limestone slopes between the north-western suburbs of the town and the mouth of the river Timavo towards Monfalcone.

All the species present in the region, are also present in the zone of Trieste. *Castanea sativa*, a SE-European element, grows in oak woods on sandstone, mainly in humid and colder sites, in

the northern outskirts of the town and towards the South, near Muggia, bordering on Slovenia. *Fagus sylvatica*, an European element, is not spontaneous in the zone of Trieste; on the Karst plateau, beech trees were planted some time ago between the localities of Basovizza and Padriciano, giving rise to a small experimental beechwood. The *Aremonio-Fagion* alliance (Marincek et al., 1992) is very frequent also in the Slovenian Karst, and beeches may occur even near the border surrounding the Trieste area. Oaks are widespread. *Quercus cerris*, an euromediterranean vegetation element, grows on deep, humid soils, mostly in the dolines of the Karst plateau and in small humid valleys. *Q. ilex*, a steno-Mediterranean element, is common in the Mediterranean maquis along the Costiera Triestina; it is also cultivated in avenues and parks within the town. *Q. petraea*, an European element, forms rather extensive woods on sandstone slopes with acid soils that surround the town. *Q. pubescens*, a pontic element, forms open woodland, particularly abundant on the Karst plateau, on dry calcareous ground. *Q. robur*, an European element which needs humid environments, is rare. *Q. rubra*, an adventitious species, is rarely cultivated and naturalized. *Q. tommasinii*, a SE-European element, is seldom found in thermophilous woodland.

A great amount of airborne pollen grains of Fagaceae was collected with a Cour trap in the atmosphere of Trieste (Rizzi Longo, 2003); other very common pollen grains are Cupressaceae, Urticaceae, *Ostrya*, *Pinus*, Poaceae and Moraceae (Rizzi Longo, 1990, 2003; Rizzi Longo and Martini, 2000). Moreover, aerobiological studies with a Hirst trap have been carried out on *Ambrosia* (Pizzulin Sauli et al., 1992), Betulaceae-Corylaceae (Larese Filon et al., 2000), Oleaceae (Larese Filon et al., 1998) and Urticaceae (Rizzi Longo et al., 2004).

Given the great interest of Fagaceae pollen for various purposes, a detailed study of their seasonal variations with regard to the main meteorological parameters has been undertaken.

2. Materials and methods

Airborne pollen sampling in Trieste was carried out in the same location and by the same

operator from 1990 to 2003. Airborne pollen was collected using a Hirst type 7-day volumetric spore trap (Burkard until 1999, VPPS 2000 Lanzoni since 2000) placed 20 m above ground level on the Bastione Fiorito of San Giusto Castle, in the town centre. Sampling method, slide preparation and data interpretation were performed according to the standard method adopted by the Italian Aeroallergen Network (Mandrioli, 1990).

Pollen grains of *Castanea*, *Fagus* and *Quercus* are separately counted, given their known morphological differences (Faegri and Iversen, 1964; Moore et al., 1991), and the three genera are individually and then cumulatively (as Fagaceae) assessed. The pollen data are expressed as pollen grains per cubic meter of air (p/m^3). For graphic presentation, the daily variations for each year are presented from March 15th to June 20th for *Fagus* and *Quercus*, and from May 10th to August 15th for *Castanea*. These periods were chosen since very small daily amounts of pollen grains of these taxa were found in the other periods of the year. For each year, the main pollen season (MPS) was determined by taking 90% of the annual total recorded pollen concentration, using cumulative values (Nilsson and Persson, 1981). Starting and ending dates were set to correspond to the days when the sum of the daily concentrations reaches 5% of the total sum until the time when the sum reaches 95%. Because of the malfunctioning of the trap during the MPS, the data of *Fagus* and *Quercus* for 1997 are incomplete, and the aerobiological parameters are missing. The mean daily counts of the pollen grains of Fagaceae for the studied years (1999–2003) are presented on the entire pollen season period. The calculations of these averages take the presence of missing data of 1997 into account.

Spearman's correlation coefficient was used to establish the relationship between the daily pollen counts and some daily meteorological parameters: mean, maximum, minimum and accumulated temperature, relative humidity, rainfall and accumulated rainfall, mean wind speed. These data were supplied by the Department of Earth Sciences, University of Trieste, whose meteorological station (Trieste) is located 700 m west of the pollen sampling site. Linear regression analysis has been applied to evaluate the influence of the mean and maximum temperatures on the MPS start of the

three genera. Statistical analysis has been carried out by SPSS (2004) and STATISTICA (2002) software packages.

3. Results

3.1. *Castanea*

The pollen shedding time usually occurs from June to the beginning of August. The pollen pattern (Figure 1) shows successive peaks taking place from mid June to mid July, but *Castanea* pollen may frequently be found in air samples even when the flowering season is over. The peaks (2 or 3 or several) alternate with days of low pollen concentrations. Every year shows a different pattern with different numbers and periods of the peaks.

The annual sums of the daily pollen concentrations and other aerobiological parameters in the years from 1990 to 2003 are given in Table 1. The mean value of the annual sums is 606, with a lowest total of 261 in 2002, and a highest annual total of 1.081 in 1998. From 1995, the total tended to increase. The percentage of the chestnut annual sum with respect to the total annual sum is rather low, ranging from 0.64% in 2002 to 2.55% in 2003, with a mean value of 1.32 %.

The highest daily pollen values usually occur in late June or beginning of July, with the earliest peak occurring in 2003, on day nr 163 (12 June) and the latest in 1991, on day nr 202 (21 July), when an accumulated temperature of respectively 1936.2 and 2649.5 °C is reached. On average, the maximal daily count occurs on day nr 179 (28 June). The mean daily maximum is $53 \text{ p}/\text{m}^3$, with the highest value of 110 in 1998, and the lowest of 23 in 2002. The daily percentage of *Castanea* grains with respect to the daily total pollen catch is usually high, on average reaching one third of the total airborne pollen content (32.51%) in the peaking day.

The average MPS starting date is on day nr 163, 12 June. The duration of the MPS ranges between 31 and 65 days. The mean length of the MPS is 43 days. From year 1995, the end of season shows a trend towards earlier dates, resulting in a shorter length of MPS.

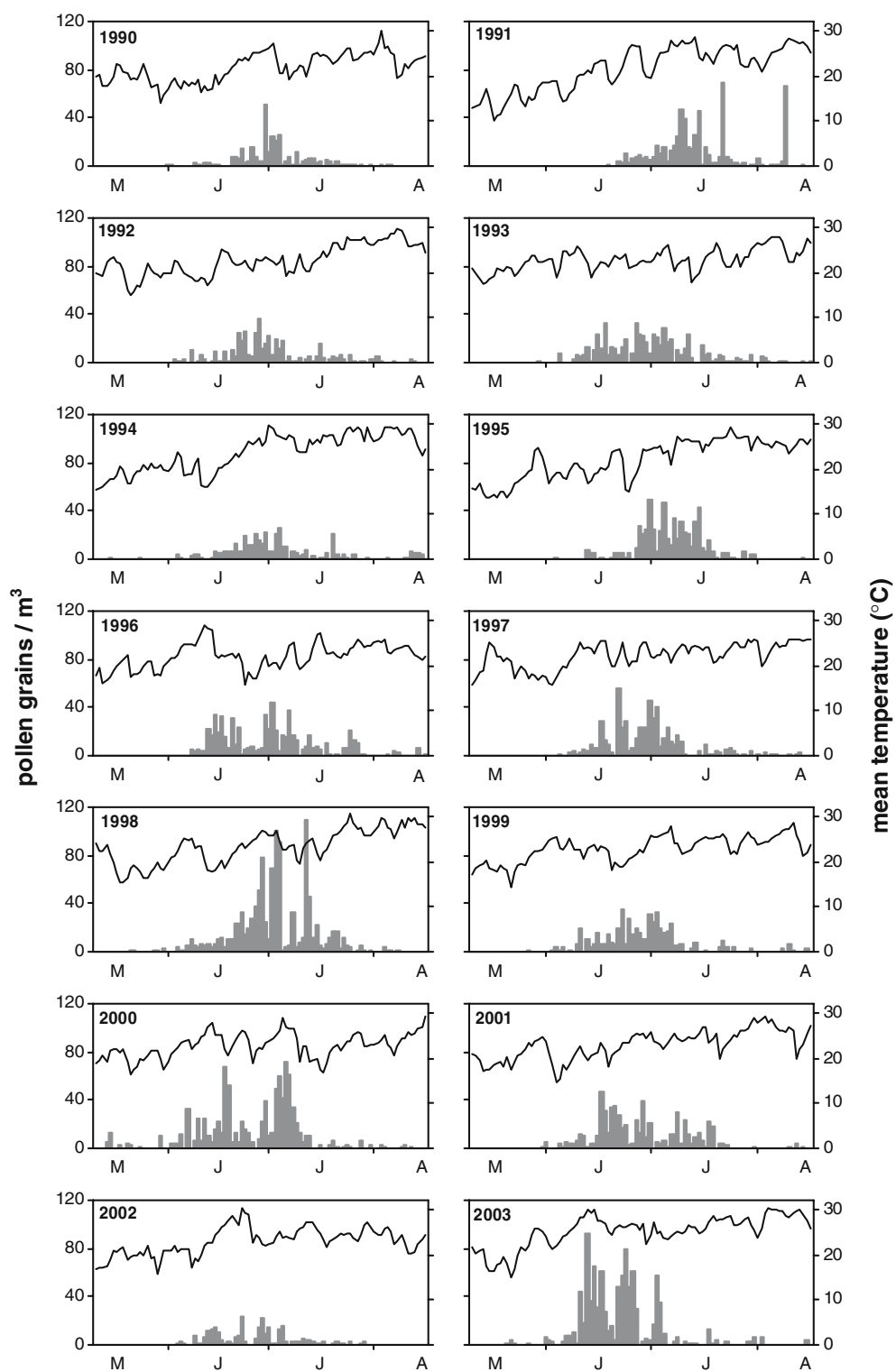


Figure 1. Annual variation in daily counts of airborne *Castanea* pollen and mean temperature in Trieste in each year from 1990 to 2003.

Table 1. Aerobiological parameters for *Castanea* pollen in Trieste in the years from 1990 to 2003

	Annual total	Date of peak-day	Peak value (p/m ³)	Acc T (°C) at peak-day	Starting date of MPS	Ending date of MPS	Length of MPS (days)
1990	319	29-Jun (180)	51	2386.8	11-Jun (162)	20-Jul (201)	39
1991	577	21-Jul (202)	69	2649.5	25-Jun (176)	8-Aug (220)	44
1992	417	27-Jun (179)	36	2208.2	7-Jun (159)	31-Jul (213)	54
1993	580	17-Jun (168)	33	2003.6	11-Jun (162)	1-Aug (213)	51
1994	392	3-Jul (184)	26	2530.1	9-Jun (160)	13-Aug (225)	65
1995	598	30-Jun (181)	49	2223.6	21-Jun (172)	22-Jul (203)	31
1996	638	1-Jul (183)	44	2266.4	12-Jun (164)	26-Jul (208)	44
1997	571	21-Jun (172)	56	2173.0	13-Jun (164)	23-Jul (204)	40
1998	1081	11-Jul (192)	110	2667.0	12-Jun (163)	20-Jul (201)	38
1999	511	22-Jun (173)	36	2171.1	10-Jun (161)	22-Jul (203)	42
2000	940	5-Jul (187)	72	2578.5	3-Jun (155)	12-Jul (194)	39
2001	619	16-Jun (167)	47	2188.0	10-Jun (161)	18-Jul (199)	38
2002	261	22-Jun (173)	23	2242.9	8-Jun (159)	20-Jul (201)	42
2003	983	12-Jun (163)	93	1936.2	8-Jun (159)	18-Jul (199)	40
mean	606	28-Jun (179)	53	2301.8	12-Jun (163)	25-Jul (206)	43

In brackets number of days from 1st January.

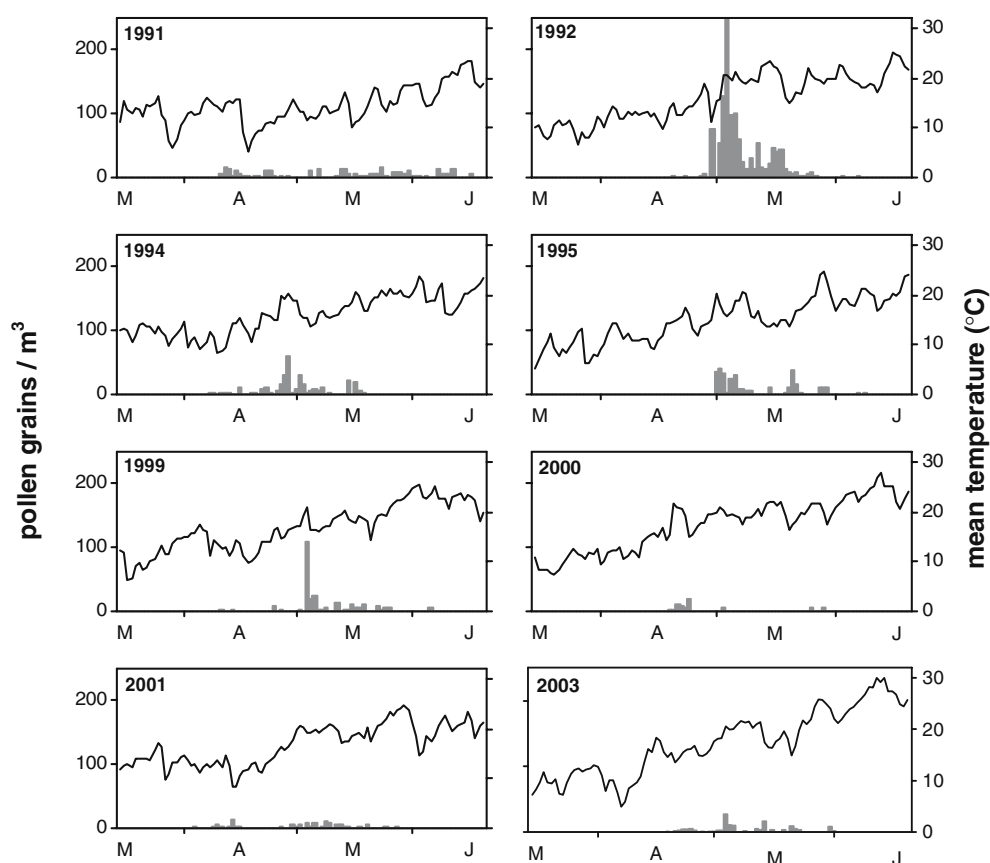


Figure 2. Annual variation in daily counts of airborne *Fagus* pollen and mean temperature in Trieste in years from 1990 to 2003 having peaking values higher than 10 p/m³.

3.2. *Fagus*

The seasonal variations in the daily pollen concentrations of *Fagus* and in the mean temperature are shown in Figure 2 only for the eight individual years in which the peaking values exceed 10 p/m³. In the years not showed, only few pollen grains of *Fagus* are sporadically captured during the pollen season. The main pollen period takes place usually from mid April to mid May. Year 1992 displays an exceptional pollen shedding, with very high peaking values occurring in the first half of May.

The annual sums of the daily pollen concentrations and other aerobiological parameters in the years from 1990 to 2003 (excluding 1997 because of the incomplete sampling) are given in Table 2. The cumulative counts vary greatly over the years. The mean value of the annual sums is 224, with the lowest total (10) in 1990, and the highest total (1.162) in 1992. On average, the percentage of the *Fagus* annual total in respect to total pollen count is very low (0.49%); only years 1991 and 1992 display higher values (0.96 and 2.13% respectively).

The highest daily pollen values usually are found in May. On average, the maximal daily count occurs on day nr 124 (4 May). The mean daily maximum is 43 p/m³, with the highest value of 246 in 1992, and the lowest of 2 in 1990. The daily percentage of *Fagus* grains in respect to the

daily total pollen grains is usually very low, on average below 4% even in the peak day.

On average, the MPS starts on day nr 109, 19 April. The duration of the MPS ranges between 20 days and 71 days. The mean length of the MPS is 41 days.

3.3. *Quercus*

All years display a seasonal pattern (Figure 3) with multiple peaks, which alternate with days of lower pollen concentrations. The main dispersal time of oaks takes place usually from mid April to late May, but it may shift earlier or later, especially in the start.

The annual sums of the daily pollen concentrations and other aerobiological parameters in the years from 1990 to 2003 (excluding 1997 because of the incomplete sampling) are given in Table 3. The cumulative counts and the length of the MPS vary over the years. The mean value of the annual sums is 1.886, with a lowest total of 720 in 2000, and a highest total of 4.108 in 1993. The percentage of the oak annual sum in respect to total pollen count ranges from 1.85% in year 2000 to 10.36% in year 1993, with 4.10% as mean value.

The highest daily pollen values usually occur on the beginning of May, with the earliest peak occurring in 1994, on day nr 113 (23 April), and the latest in 1991, on day nr 135 (15 May), with

Table 2. Aerobiological parameters for *Fagus* pollen in Trieste in the years from 1990 to 2003 (excluding 1997 because of the incomplete sampling)

	Annual total	Date of peak-day	Peak value (p/m ³)	Acc T (°C) at peak-day	Starting date of MPS	Ending date of MPS	Length of MPS (days)
1990	10	5-May (125)	2	1297.7	24-Mar (83)	3-Jun (154)	71
1991	310	24-May (144)	17	1385.9	12-Apr (102)	12-Jun (163)	61
1992	1162	4-May (125)	246	1110.7	30-Apr (121)	20-May (141)	20
1993	16	5-May (125)	5	1086.8	25-Apr (115)	4-Jun (155)	40
1994	308	29-Apr (119)	59	1218.1	16-Apr (106)	17-May (137)	31
1995	330	2-May (122)	41	1124.2	1-May (121)	30-May (150)	29
1996	26	29-Apr (120)	6	986.7	20-Apr (111)	19-May (140)	29
1998	63	11-May (131)	8	1363.4	20-Apr (110)	5-Jun (156)	46
1999	278	4-May (124)	108	1165.4	25-Apr (115)	25-May (146)	31
2000	69	24-Apr (115)	19	1023.4	20-Apr (111)	29-May (150)	39
2001	145	14-Apr (104)	14	1032.8	9-Apr (99)	28-May (148)	49
2002	54	19-May (139)	6	1496.1	15-Apr (105)	7-Jun (158)	53
2003	144	4-May (124)	27	1081.8	22-Apr (112)	31-May (151)	39
mean	224	4-May (124)	43	1182.5	19-Apr (109)	30-May (150)	41

In brackets number of days from 1st January.

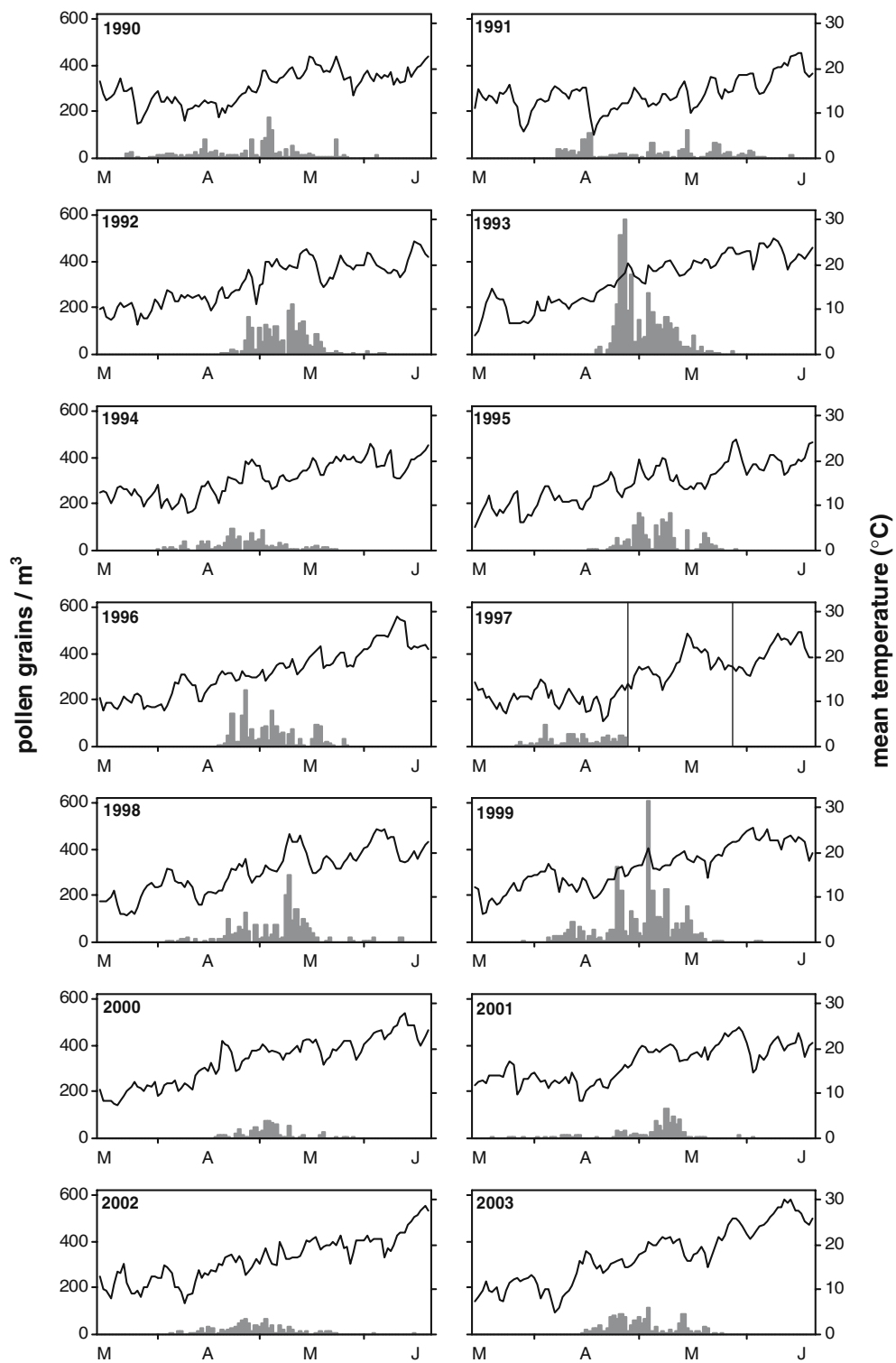


Figure 3. Annual variation in daily counts of airborne *Quercus* pollen and mean temperature in Trieste in each year from 1990 to 2003. Vertical lines drawn in year 1997 show the period with lacking counts.

Table 3. Aerobiological parameters for *Quercus* pollen in Trieste in the years from 1990 to 2003 (excluding 1997 because of the incomplete sampling)

	Annual total	Date of peak-day	Peak value (p/m ³)	Acc T (°C) at peak-day	Starting date of MPS	Ending date of MPS	Length of MPS (days)
1990	1616	4-May (124)	173	1280.6	31-Mar (90)	24-May (144)	54
1991	1438	15-May (135)	121	1259.8	9-Apr (99)	2-Jun (153)	54
1992	2352	11-May (132)	213	1248.6	27-Apr (118)	19-May (140)	22
1993	4108	27-Apr (117)	577	943.5	24-Apr (114)	16-May (136)	22
1994	1211	23-Apr (113)	93	1113.3	8-Apr (98)	18-May (138)	40
1995	1763	1-May (121)	164	1106.0	25-Apr (115)	21-May (141)	26
1996	1869	27-Apr (118)	245	955.6	23-Apr (114)	20-May (141)	27
1998	2186	10-May (130)	289	1341.0	19-Apr (109)	22-May (142)	33
1999	3806	4-May (124)	608	1165.4	11-Apr (101)	16-May (136)	35
2000	720	3-May (124)	74	1190.9	21-Apr (112)	20-May (141)	29
2001	1056	9-May (129)	127	1423.1	8-Apr (98)	16-May (136)	38
2002	1026	3-May (123)	68	1201.9	13-Apr (103)	21-May (141)	38
2003	1365	4-May (124)	118	1081.8	19-Apr (109)	20-May (140)	31
mean	1886	4-May (124)	221	1177.8	16-Apr (106)	21-May (141)	35

In brackets number of days from 1st January.

an accumulated temperature of 1113.3 and 1259.8 °C, respectively. On average, the maximal daily count occurs on 4 May (124). The average peak value is 221 p/m³, with the highest value of 608 in 1999, and the lowest of 68 in 2002. The daily percentage of *Quercus* grains in respect to the daily total pollen grains exceeds, on average, 6% from mid April to mid May and reaches 16% in the main peaking days.

The average MPS starting date is on day nr 106, 16 April. The MPS ends averagely on day nr 141, 21 May. The duration of the MPS is very variable ranging between 22 and 54 days. The mean length of the MPS is 35 days.

3.4. *Fagaceae*

The seasonal course of the average of the daily pollen concentrations of *Fagaceae* for the studied years, from March 15th to August 15th, is shown in Figure 4. The share of *Quercus*, *Fagus* and *Castanea* in the daily amount of *Fagaceae* is indicated by three different shades. The line shows the seasonal course of the average of the 5-days running means.

A sporadic presence of pollen grains of *Fagaceae* already occurs from late March. From the beginning of April, the daily pollen levels increase step by step until the first week of May, when, on day nr 124 (4 May), they reach the highest mean daily value (145 p/m³); subsequently, the mean

counts decrease until the beginning of June. From early June the mean values increase again until the beginning of July, almost reaching 30 p/m³ on day nr 183 (2 July), after which they begin to decrease until mid August. During April and May, the daily percentage of *Fagaceae* in respect to the daily total pollen catch is rather low (16% in the highest peaking day); during June and July it becomes higher and reaches, on the peaking day, about a third of the total airborne pollen content.

The seasonal course of the average of the 5-days running means for the studied years shows two main pollen periods, in April–May and in June–July, due to the pollen shedding of *Quercus* and *Fagus* the first, and *Castanea* the second. The first main period displays three peaks, in mid April, late April and early May. The small peak occurring on mid April is due to the early flowering of trees of *Q. petraea* growing on the hills near the town. The higher following peaks are due to grains coming from trees of *Q. pubescens* growing in the outskirts of the town the former, in late April, and from oaks growing on the Karst plateau (or further away) the latter, in early May. This latter peak is the highest, also because the pollen grains of *Fagus*, whose average values are strongly influenced by the exceptional pollen shedding observed in year 1992, are added to those of *Quercus*. At the beginning of June the first main pollen period of

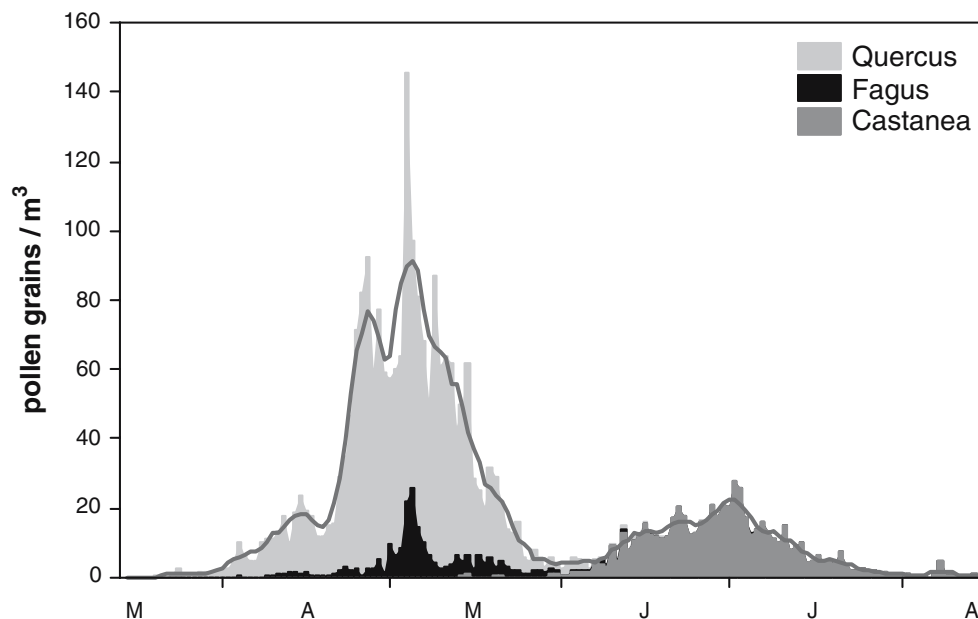


Figure 4. Daily variation of the average of the daily pollen counts of Fagaceae in Trieste for the studied years (1990–2003). Different shades show the share of the three genera. The line shows the 5-days running mean.

Fagaceae ends, the season of oaks and beeches being over. From early June, *Castanea* begins to flower and the values of Fagaceae increase again until the beginning of July, then finally decrease. This second main pollen period of Fagaceae displays lower values than the first one.

Figure 5 shows the annual sums of Fagaceae pollen, in the years from 1990 to 2003. The share of *Quercus*, *Fagus* and *Castanea* in the annual sums is indicated by three different shades. Year 1997 shows only *Castanea* total because of the incomplete sampling for *Fagus* and *Quercus*. The

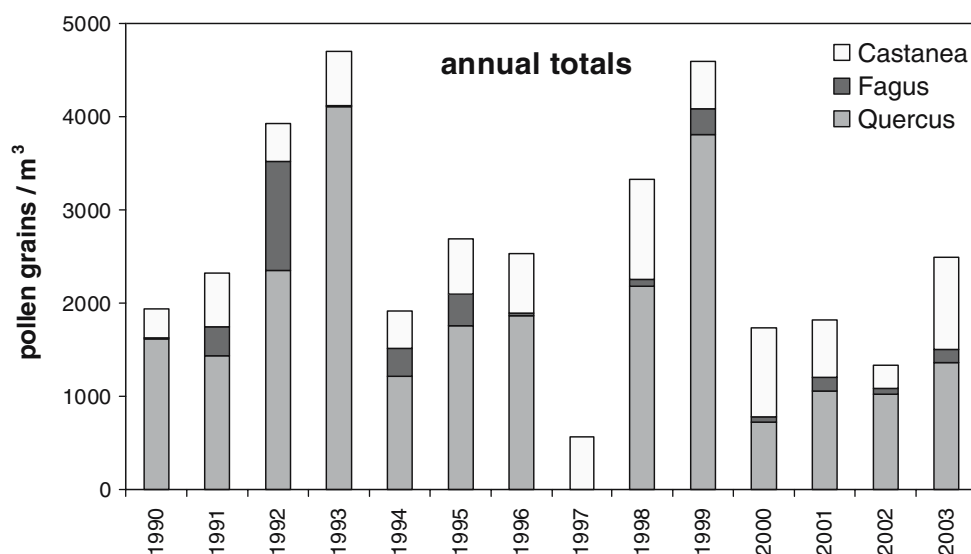


Figure 5. Trieste Fagaceae totals 1990–2003. Different shades show the share of the three genera excluding 1997 because of the incomplete sampling for *Fagus* and *Quercus*.

annual sums of Fagaceae are rather variable in the studied years. The mean value is 2.719, with a lowest total of 1.341 in 2002, and a highest total of 4.704 in 1993. Years 1992 and 1999 display a rather high annual sum too, respectively 3.931 and 4.595. The percentage of the Fagaceae annual sum in respect to total pollen count ranges from 3.29% in year 2002 to 11.86% in year 1993, with 6.01% as mean value.

The highest values for *Quercus* occur in 1993 and 1999, for *Castanea* in 1998, 2000 and 2003, for *Fagus* in 1992. The share of *Quercus* in the Fagaceae annual sum is very high, ranging from 41.6% in year 2000 to 87.3% in 1993, with a mean value of 67.25%. *Castanea* contributes to a lesser extent, its share ranging from 10.6% in year 1992 to 54.4% in year 2000, on average 24.8%. The percentage of the *Fagus* annual sum in respect to Fagaceae annual sum is negligible (7.91% as mean value), ranging from 0.3% in year 1993 to 29.6% in year 1992, in which an exceptional beech pollen shedding was observed.

3.5. Correlations with meteorological parameters

Table 4 shows the Spearman's correlation coefficients between the daily pollen concentrations (expressed as p/m^3) and some daily meteorological parameters (mean, minimum and maximum temperature expressed in $^{\circ}\text{C}$; relative humidity; rainfall expressed in mm; mean wind speed expressed in m/s). The non parametric Spearman's coefficient is chosen since the daily pollen counts are not normally distributed. The correlations have been calculated separately for each year and for each taxon. The degree of correlation between pollen concentrations and meteorological variables is different from year to year. The correlations between daily pollen concentration and temperature (mean, minimum, maximum) result usually positive and only in some years are significant. The level of significance results high only in few cases for *Fagus*, more frequently for *Castanea* and *Quercus*. The values of correlation between the daily pollen concentration and relative humidity are almost always negative and often with a high level of significance for *Fagus* and *Quercus*. No significant correlations between daily pollen concentration and rainfall and mean wind speed are found for *Castanea*, while both for *Fagus* and *Quercus* they result respectively

significantly negative and positive only in some years.

Neither pollen totals nor start of MPS result correlated with meteorological parameters in the previous year; no correlations are found between the start of MPS and current meteorological data in the last 10–15 days preceding the start. On the contrary, significantly negative relationships are highlighted between start of MPS and current temperatures (mean and maximum) in time periods of different length preceding the pollination. The increase of temperature in the first months of the year remains therefore a factor determining the beginning of pollen release. The highest levels of significance are reached in the correlations between start dates and mean and maximum temperatures in a period of 30 days beginning a month and a half before the start of MPS, corresponding to March for *Fagus* and *Quercus*, and May for *Castanea*. Moreover, *Fagus* and *Quercus* start dates result positively correlated between themselves ($r=0.862$) with a high level of significance ($p=0.000$). The beginning of pollen shedding of *Fagus* and *Quercus*, therefore, seems to be influenced in the same way by current meteorological data before the start of season. The regression graphs with 95% confidence bands are shown in Figure 6; the equations of linear regression models for the start of MPS of the three genera of Fagaceae, as functions of the mean and maximum temperatures in March for *Fagus* and *Quercus* and May for *Castanea*, are also reported. All three graphs show that the start of MPS (y), expressed as the number of days from 1st January, comes earlier according to higher temperature values (x) during March for *Fagus* and *Quercus*, and May for *Castanea*. More dispersion of the point around the regression line for *Fagus* is confirmed by a lower correlation value with respect to the two other genera.

4. Discussion

Overall, the pollen shedding course of the Fagaceae in Trieste corresponds to that already described during the pollen season in Europe (Ickovic and Thibaudon, 1991): *Quercus* and *Fagus* in April and May, *Castanea* in June and July. The highest values occur from late April to

Table 4. Spearman's correlation coefficients for daily pollen counts of the three genera of Fagaceae according to the meteorological parameters for each year from 1990 to 2003

	<i>d.f.</i>	T_{mean}	T_{min}	T_{max}	H_{rel}	R	W
<i>Castanea</i>							
1990	40	0.447**	0.449**	0.373*	-0.198	0.068	0.212
1991	45	0.540***	0.417**	0.535***	-0.185	0.027	0.121
1992	55	-0.089	-0.066	-0.107	-0.191	-0.234	0.063
1993	52	0.105	0.089	0.158	0.035	-0.057	-0.005
1994	66	-0.287*	-0.308*	-0.160	0.267*	0.092	-0.090
1995	32	0.008	0.034	0.137	-0.023	-0.236	-0.145
1996	45	0.234	0.133	0.152	0.078	0.103	-0.153
1997	41	0.168	0.240	-0.037	-0.131	-0.209	0.106
1998	39	0.711***	0.670***	0.681***	0.354*	-0.257	-0.167
1999	43	-0.006	-0.111	-0.043	-0.062	-0.081	-0.156
2000	40	0.400**	0.384*	0.318*	-0.022	-0.238	-0.057
2001	39	0.016	0.052	-0.100	-0.074	0.076	-0.085
2002	43	-0.013	-0.012	0.027	-0.145	-0.251	0.145
2003	41	0.509***	0.542***	0.477**	0.168	0.170	0.038
<i>Fagus</i>							
1990	72	-0.117	-0.160	-0.076	-0.131	0.016	0.055
1991	62	0.348**	0.253*	0.419***	-0.601***	-0.430***	0.022
1992	21	0.193	0.123	0.262	-0.148	-0.093	0.428
1993	41	-0.158	-0.245	-0.043	-0.087	0.048	0.190
1994	32	0.447**	0.316	0.524**	-0.621***	-0.338	0.308
1995	30	0.290	0.126	0.372*	-0.791***	-0.473**	0.480**
1996	30	0.143	-0.084	0.209	-0.460**	-0.200	-0.073
1998	47	0.198	0.197	0.256	-0.488***	-0.243	0.114
1999	32	0.255	0.205	0.346	-0.601***	-0.075	0.551***
2000	40	0.244	0.085	0.218	-0.145	0.015	-0.110
2001	50	0.185	0.134	0.228	-0.419**	-0.207	0.144
2002	54	-0.350**	-0.356**	-0.234	0.003	0.224	0.190
2003	40	-0.269	-0.308	-0.164	-0.030	-0.152	-0.056
<i>Quercus</i>							
1990	55	0.037	-0.018	0.125	-0.322*	-0.186	0.020
1991	55	0.383**	0.213	0.479***	-0.409**	-0.154	0.171
1992	23	0.280	0.181	0.221	-0.166	0.086	0.102
1993	23	0.216	-0.107	0.366	-0.500*	-0.081	0.216
1994	41	0.326*	0.289	0.337*	-0.566***	-0.338*	0.204
1995	27	0.505**	0.485**	0.534**	-0.649***	-0.450*	0.511**
1996	28	0.008	-0.045	0.034	-0.591***	-0.165	0.315
1998	34	0.450**	0.393*	0.482**	-0.584***	-0.289	0.217
1999	36	0.539***	0.584***	0.586***	-0.542***	-0.284	0.285
2000	30	-0.275	-0.358	-0.109	-0.115	0.127	0.261
2001	39	0.716***	0.670***	0.704***	-0.536***	-0.438**	0.246
2002	39	-0.193	-0.246	-0.171	-0.129	0.032	0.174
2003	32	-0.318	-0.251	-0.333	0.129	0.233	0.449**

Correlations are non available for *Fagus* and *Quercus* in year 1997. T_{mean} mean daily temperature, T_{min} minimum daily temperature, T_{max} maximum daily temperature, H_{rel} relative humidity, R daily rainfall, W mean wind speed. *d.f.* = degree of freedom. Level of significance: * $p \leq 0.05$; ** $p \leq 0.01$, *** $p \leq 0.001$.

mid May and are due to the main pollen shedding of oaks and beeches. Due to the scarcity of beech trees in the zone of Trieste, the share of *Fagus* in these values is nevertheless significant only in a

few years, when an exceptional blooming and/or specific weather conditions occur, which allow a medium/long range transport from Slovenia or Julian Alps; in the other years, this share is

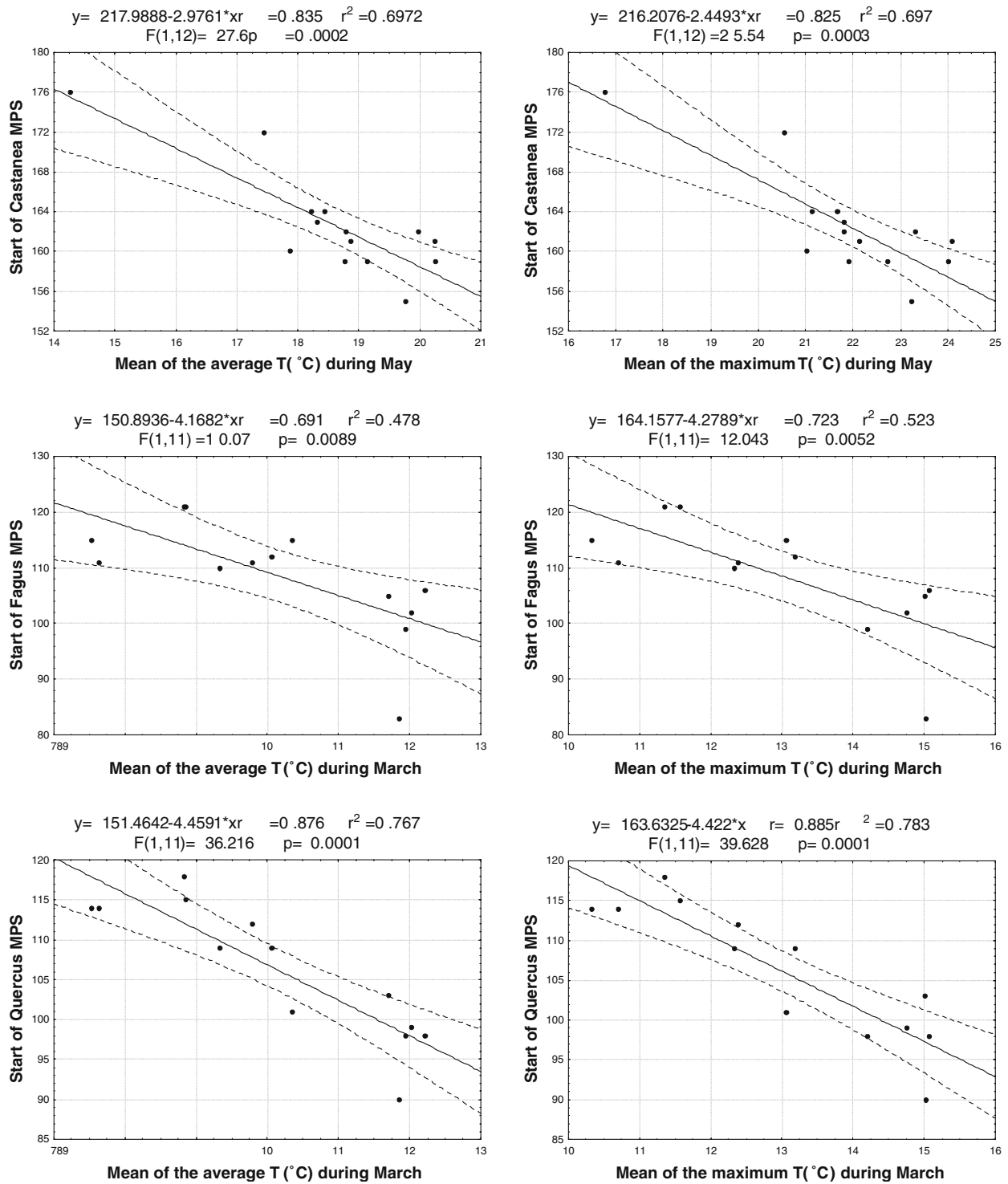


Figure 6. Regression graphs with 95% confidence bands between the start of MPS (y =number of days from 1st January) and temperature (x). Complete regression equations and coefficients are also showed.

negligible. In spring time, almost all Fagaceae pollen is therefore usually due to the pollen shedding of *Quercus*, whose various species are widespread around the town and on the Karst plateau, and characterize the natural landscape of this area. On the basis of phenological observations carried out directly in the field in order to investigate the relationships between behaviour of pollen sources and aerobiological pattern, *Quercus petraea* flowers before other oaks growing in the zone around Trieste and *Q. ilex* later (Rizzi Longo, 1990). The successive pollen shedding of the various species, in addition to the shift of flowering time in trees growing in different microclimatic sites, may explain the successive oak peak periods observed every year, whose higher values are especially found in late April and early May. This pattern may be connected both to the geographical complexity of the zone around Trieste and the variety of the species which flower at different times. Moreover, it must not be overlooked that pollen is also carried, by dominant winds, from nearby Slovenia, bringing about a lengthened pollen season, as occurs also for *Castanea*, whose long range transport is already well-known (Frei, 1997; Mandrioli, 1998; Peeters and Zoller, 1988). Chestnut pollen grains may come, as in Galicia (Jato et al., 2001), not only from local trees, but also from trees growing at different distances and altitudes. As a result of phenological observations carried out directly in the field from year 1991 and partially published by A.I.A. Gruppo di Lavoro di Fenologia (1998), chestnut trees growing in the outskirts of Trieste flower early and the highest pollen values found at beginning of July may be attributed to these.

The Fagaceae content of the air is mainly due to *Quercus* and *Castanea* pollen, *Fagus* usually having a scarce pollen shedding in this area. Years with a high annual sum for *Quercus* do not coincide with those years with high annual sums for *Fagus* or *Castanea*, as already observed in Brussels by Detandt and Nolard (2000). The two-year cycle, observed for *Quercus* and *Fagus* by Andersen (1980) in the Draved Forest (SW Denmark), is recognizable only in the last 6 years.

The maximum annual total of Fagaceae was registered in 1993, when a very high pollen shedding of *Quercus* occurred. Years with very high pollen total were also 1999 and 1992. In 1999, a

high pollen shedding of *Quercus* occurred again. In the year 1992, an exceptional pollen amount of *Fagus* was found, perhaps due both to grains coming from Slovenian beech forests and transported by persistent ENE wind (bora) and to a massive pollen production, as already observed, in the same year, for *Abies*, *Picea*, *Pinus*, *Olea* and other taxa (Larese Filon et al., 1998; Rizzi Longo, 2003); for these taxa, therefore, 1992 appears as a good mast year. Also the year 1998 shows a rather high pollination of Fagaceae, with a very high contribution of *Castanea*, that reaches its highest airborne pollen amount in this year.

A short shift in flowering time and pollen release usually occurs from year to year. In some years, even a shifting of 15–20 days is observed, and the MPS starts and/or ends earlier or later.

Neither pollen totals nor start of MPS result correlated with meteorological parameters (summer temperature or drought) in the previous year, as found for *Quercus* and *Fagus* by Andersen (1980) and for *Quercus* by Corden and Millington (1999). Current temperatures before the pollen season influence the start of flowering, as shown for *Quercus* by García-Mozo et al. (2000) and Rodríguez-Rajo et al. (2003). Also in Trieste, significative correlations are found between mean and maximum temperatures before the flowering time and the start of MPS of *Quercus*, *Fagus* and *Castanea*.

5. Conclusion

The pollen shedding course of the Fagaceae in Trieste corresponds to that already described in Europe: *Quercus* and *Fagus* in April and May, *Castanea* in June and July. The highest values occur from late April to mid May and are due to the main pollen shedding of oaks and beeches. Variations in the annual sum of Fagaceae pollen, probably depending on meteorological features and/or physiological cycles, are observed. No positive nor negative long-term trends in Fagaceae pollen shedding are found in Trieste between 1990 and 2003. No cyclic variations were observed.

Only in some years positive significant correlations between the daily pollen values and the temperatures (mean, minimum and maximum) especially for *Castanea* and *Quercus* and negative ones with relative humidity for *Fagus* and

Quercus are found. *Fagus* and *Quercus* start dates result positively correlated between themselves with a high level of significance; the beginning of the pollen shedding of *Fagus* and *Quercus*, therefore, seems to be influenced in the same way by current meteorological data before the start of season. Significant correlations are found between the start of MPS and the mean and maximum temperature in March for *Fagus* and *Quercus*, and May for *Castanea*.

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