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A Study of Airborne Pollen Grains in Karak, Jordan for the Period Extending from March 2005 to February 2007

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Abstract: In this study, pollen grains in the atmosphere of Karak district, Jordan were studied based on the results of 2 years for the period extending from March 2005 to February 2007. Daily and monthly counts were carried out using Burkard volumetric pollen traps. Daily slides were prepared and investigated in 4 periods a day. Dispersal rates and the number of pollen grains per cubic meter were calculated. The maximum daily pollen count was 52,300 and the minimum daily pollen count was zero. The maximum monthly pollen count was 377,015 in March, 2005 and 242, 767 in April 2006 whereas the minimum monthly pollen count was 221 and 123 in August 2005 and December 2006, respectively indicating inter and intra-year variations in pollen counts which attributable to weather conditions especially rainfall fluctuation and distribution during the growing season. Intradiurnal variations in pollen counts were also observed, the pollen dispersal during the 24 h day was highest between 8.00-2.00 pm. Total pollen grains consisted of 62.1% from arboreal plants and 35.9% from non-arboreal plants. *Pinus* sp., *Cupressus* sp., *Quercus* sp., *Olea* sp., *Salix* sp., Urticaceae, Calycotome, Moraceae, Rosaceae, Chenopodiaceae/Amaranthaceae, Gramineae, *Plantago* sp. and *Rumex* sp. released the greatest amounts of pollens in Karak's atmosphere. Levels of the majority of allergic pollen types peaked in March to May which are usually the worst times of the year for people allergic to pollen in Karak district. Atmospheric pollen concentrations from September to February were less than those in other months.

Key words: Airborne pollen, aerobiology, pollen grains, palynology, Karak, Jordan

INTRODUCTION

The atmospheric pollen concentrations were studied from several aspects including agricultural situations, environmental importance and allergic diseases (Faegari and Iversen, 1975). Regular pollen and spore reports and forecasts provided by national aeroallergen networks play the main role in prevention of allergic diseases therefore, a reliable pollen forecast is of great importance for allergologist and for allergic people as well. For this reason, annual pollen calendars were prepared in many countries (Davie *et al*., 1963; Aytuo *et al*., 1990; D'Amato *et al*., 1998; Bicakci *et al*., 2005). Knowledge of the local flora, native, endemic or introduced, enhances the probability of correctly identifying pollen grains which can affect human activities (Halwagy and Halwagy, 1984; Karim and Al-Quran, 1988; Moor and Webb, 1978; Zohary, 1973). There is evidence from all over the world that the prevalence of allergic diseases induced by pollen has increased and has depended on palynological background (Corden and Millington, 1999; Emberlin *et al*., 2002; Garcia-Mozo *et al*., 2002). There are many environmental factors that account for changes in the number of pollen grains in the atmosphere such as temperature, rainfall and wind speed (Frenguelli *et al*., 1992; Dahl and Strandhede, 1996; Laaidi, 2001; Jato *et al*., 2002).

The aerobiology of Jordan, Palestine and the Middle East countries in respect to surveyed airborne pollen grains were studied especially from the pollen count aspect by many investigators during the time period 1959-1984 (Al-Eisawi and Dajani, 1983; Davie *et al*., 1963; Davis, 1969; Halwagy and Halwagy, 1984). Similar palynological studies were carried out in different parts of the world by other investigators.

One of them studied the pollen component of bioaerosol in the air of Novosibirsk (Golovko *et al*., 1997) while Mathias-Maser (1997) studied the primary biological aerosol particles as insoluble components to the atmospheric aerosol over the South Atlantic ocean. Cerceau-Larrival *et al*. (1996) investigated pollen as a bio-indicator of bioaerosol. These palynological investigations of airborne pollen grains and dust storms were studied in terms of dispersal, concentration of pollen

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grains in the air, pollen counts and seasonal air spores in the atmosphere of specific hot spots (Zohary, 1973; Stenzel, 2000; Van Der Ham *et al.*, 2001; Suarez-Cervera *et al.*, 2001; Van Wichelen *et al.*, 1999; Victor and van Wyk, 1999; Villodre and Giarcia-Jacas, 2000).

During the spring and early summer many patient cases exhibiting seasonal rhinitis and/or bronchial asthma were reported by the various medical centers and hospitals in Jordan especially from both civilian and military wings of Karak Hospitals. This time interval is known in Karak to be caused by the effect of pollen allergens as shown by prick tests with pollen extracts. Therefore, this study was conducted to achieve the following objectives:

- To determine the total airborne pollen grains in the atmosphere of Karak, pollen releasing periods and to present pollen calendar of Karak based on the results of 2 years extending from March 2005 to February 2007
- To investigate when pollen concentrations reached their highest levels throughout the year and to determine intradiurnal variations in pollen concentrations
- To give an indication of relationship between the pollen dispersal and the development of allergic symptoms in Karak area
- To identify and quantify atmospheric pollen type in Karak district

These four research objectives are the vital ones to draw a clear image about the airborne pollen of Karak's environment in southern Jordan (Al-Quran, 2004 a, b). To the best of the knowledge this study is the first investigation in the southern part of Jordan (Karak) which was funded from Mutah University, the center of higher education and scientific research.

MATERIALS AND METHODS

The annual pollen counts and the different taxa constituting the airborne pollen grains were quantitatively surveyed in Karak area, Jordan. The dominant species in Karak habitat are shown in Table 1 as reported by Karim and Al-Quran (1988) and Mishra *et al.* (2002). The study area is located 3 km west of the city of Karak (31°11'N, 35°42'E) near Sarah springs within the Karak mountains at an elevation ranging from 800-1100 m above sea level (Fig. 1).

This area is dominated by a Mediterranean environment but it is influenced by the westerly air currents associated with winter precipitation, a cold snowy winter is the general condition. The mean long term annual precipitation is about 350 mm during winter extending from November to April while spring months (March and April) tend to be wetter with about 100 mm long-term monthly average precipitation. The mean summer temperature is 24°C while the average winter temperature ranges from 2-6°C. Transpiration rates are 1300 mm year^{-1}. The rock pH value is 6.5-7.0, the soil texture ranges from loamy-silt to silt-clay to grave-clay (The Jordan Meteorological Department reports in 1990-2003; Karim and Al-Quran, 1988; Zohary, 1973).

The volumetric Burkard trap was used in this study to collect the atmospheric pollen grains concentrated in the air. Pollen counts were checked weekly and total weekly counts were converted to the number of pollen grains m^{-3}. The sampler was fixed on the roof of a hilly place about 10 m above the ground level. This site where the trap was fixed is surrounded by many topographic hills especially towards the Al-Mazar and Al-Karak directions (Fig. 1). So, the position of the trap is not the only factor affecting the pollen distribution and atmospheric pollen concentration. The total daily pollen counts as well as monthly counts were calculated, slides

Table 1: The dominant trees and shrubs in Karak habitat and their plant species showed higher plant densities in lower altitudes of south-west facing slopes than higher altitudes of north-east facing slopes

Common name	Available species
Dominant trees frequently seen in the springs' sides	Three *Quercus* tree species (*Quercus calliprinos* Webb, *Q. ithaburensis* Decne. and *Q. Aegilps* L.), *Platanus orientalis* L. (Oriental plane), *Pinus halepensis* L. (Halap pine), *Prunus laurocerasus* L. (Cherry Laurel), *Rosa canina* L. (Wild rose), *Populus* sp. L. (Poplar) and *Salix* sp. L. (Willow) and *Arbutus andrachne* L. (Strawberry tree), *Rubus sanctus* L.
Shrubs	(*Styrax officinalis* L., *Cistus creticus* L., *Cistus salviifolius* L., *Atriplex halimus* L., *Calycotome villosa* (Poir.) Link, *Retema raetam* L. and *Sarcopoterium spinosum* (L.) Spach., *Hypericum calysinum* L., *P. pinaster* L., *Antirrhinum majus* L. (Snapdragon), *Linaria genistifolia* L., *Laurus nobilis* L. (Laurel)
Plant species showed higher plant densities in lower altitudes of south-west facing slopes than higher altitudes of north-east facing slopes	*Cercis siliquastrum* (Judas tree), *Juniperus* sp. L., *Ligustrum vulgare* L. (Ligustrum), *Morus alba* L. (White Mulberry), *Nerium oleander* L. and *Olea europaea* L. (Olive tree)

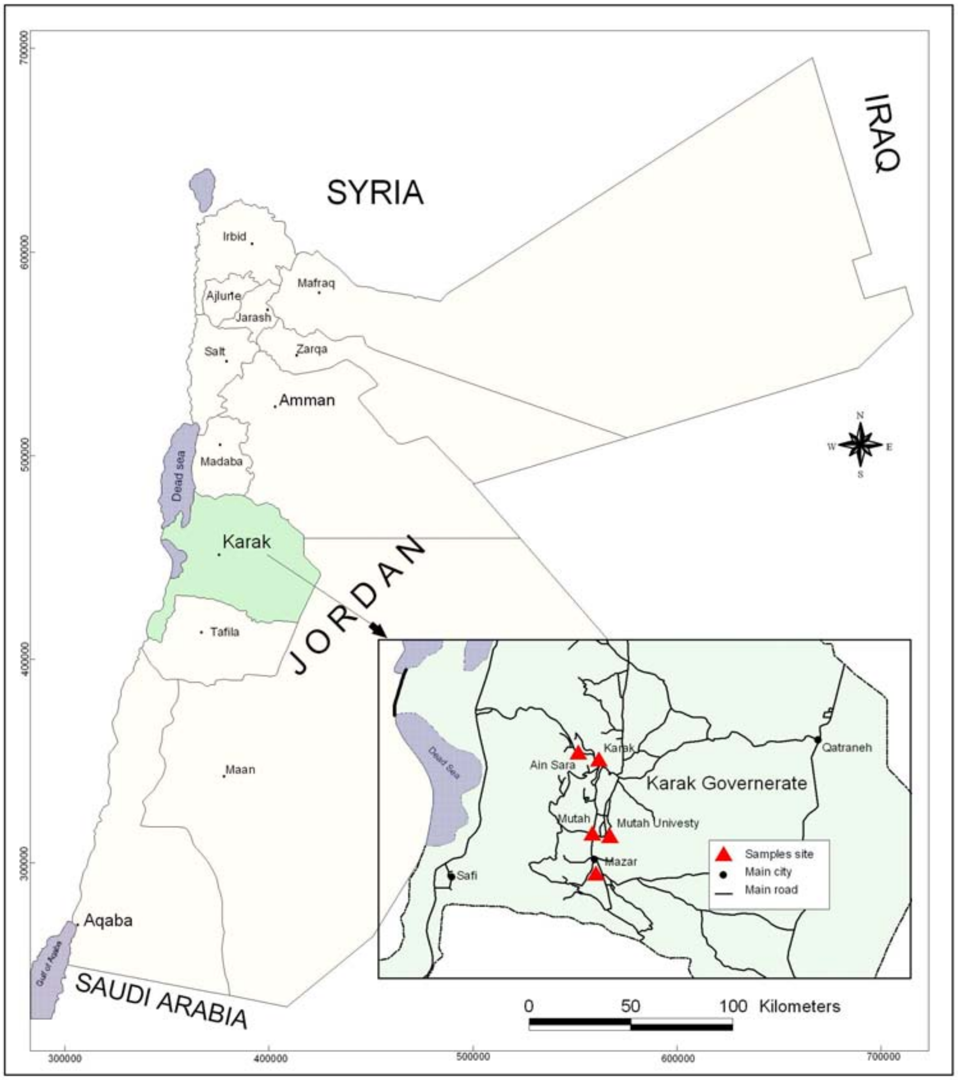

Fig. 1: Map of the study area

from strips of weekly ribbon were prepared (Davie *et al*., 1963; Davis, 1969) for further investigation. Four periods of collection were taken daily to study intradiurnal variations in pollen dispersal, namely; P_1: 2.00-8.00, P_2: 8.00-2.00, P_3: 2.00-8.00 and P_4: 8.00-2.00 am. Records of 2 full years, March 2005 to February 2007 were used in this study.

The data collected for the daily and monthly pollen counts were expressed in terms of number of pollen grains per cubic meter of the air.

The identification of pollen taxa was done with the help of reference slides, identification of pollen grains were made at least up to family or genus levels. Grains which could not be identified were considered as unidentified types.

RESULTS AND DISCUSSION

Daily pollen counts: The maximum daily count during the period extending from March 2005 to February 2006 was 52,300 and 18,760 pollen grains in March 2005 and April 2005, respectively while the period extending from June to January showed the minimum daily count (Fig. 2). Similar trends were observed for minimum daily counts and mean daily counts.

Monthly total counts: The monthly total counts were calculated by summing daily counts for each month to study the level of variability among months in total pollen dispersal (Fig. 2). During the period extending from March 2005 to February 2006, the maximum monthly pollen count

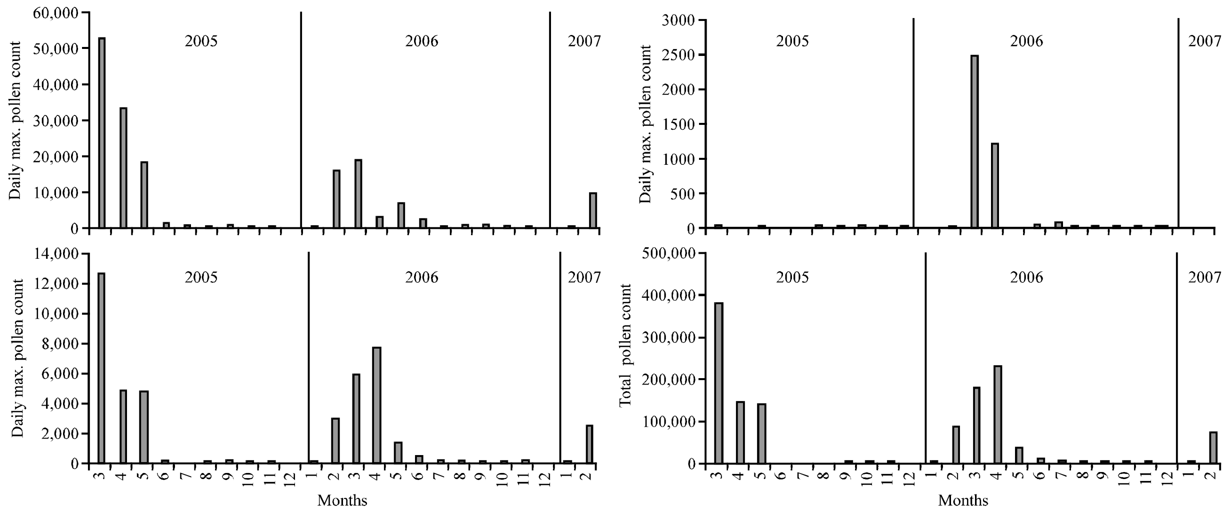

Fig. 2: Maximum, minimum, mean daily and monthly total counts of pollen grains for the period extending from March 2005 to February 2007. Numbers from 1-12 are representing months extending from January to December

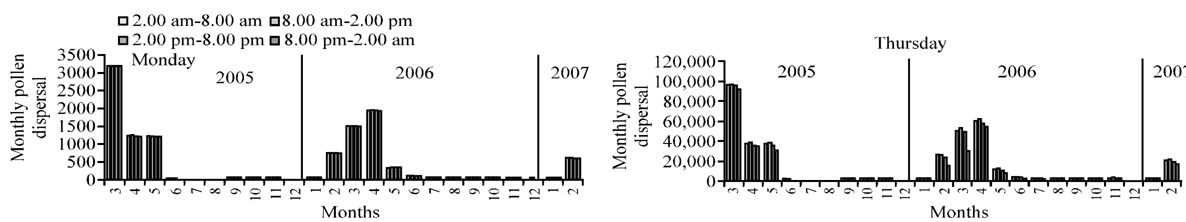

Fig. 3: Mean total monthly pollen dispersal in 6 h intervals each day for the period March 2005 to Februrry 2007. The day is divided into 4 periods: P_1:-8.00, P_2:8.00-2.00, P_3:2.00-8.00, P_4:8.00-2.00 am on Monday and Thursday. Numbers from 1-12 are representing months extending from January to December

was 377,015 in March while the minimum monthly pollen count was 215 in August 2005. During the complementary time of the next year, the maximum daily count was 242,767 in April while the minimal daily count was 123 in December. Pollen dispersal was widely fluctuated between months which were in consequence reflected on the daily pollen counts. It can now be confidently stated that in Karak district, March, April and part of May are with the largest pollen dispersal and then the pollen counts decrease gradually until they become the lowest at the end of autumn and the beginning of winter.

Daily pollen concentration: Pollen dispersal during 24 h of the day has been studied at 6 h intervals (2.00-8.00, 8.00-2.00, 2.00-8.00 and 8.00-2.00 am) throughout the day to find the maximum pollen dispersal during the day in different months. Intradiurnal variations in pollen dispersal were observed (Fig. 3). The pollen dispersal peaked between 8.00-2.00 pm (P_2 period), the hottest period of the day followed by P_1 period (2.00-8.00 am) with sunrise and P_4 (8.00-2.00 am). The pollen dispersal was at its minimum level between 2.00-8.00 pm (P_3 period).

Counts per cubic meter of air: Pollen concentrations are expressed in terms of the number of pollen grains per cubic meter of atmospheric air (Fig. 4). The difference between these counts depended on the periodic time of the day. During the period of March 2005 to February 2006, the mean daily pollen per cubic meter was 2943 pollen m^{-3} in March while the lowest values were detected from June 2005 to January 2006 (range = 1.5-9.8 pm^{-3}). During the period extending from March 2006 to February 2007, the mean daily pollen per cubic meter reached the highest level in March and April (values = 230 and 235 p m^{-3}, respectively) while the lowest pollen concentrations were detected from July to January (range = 3.7-12.7 pollen m^{-3}).

Types of the pollens present in Karak's environment: A total of 387,000 pollen grains belonging to 39 taxa were identified and recorded in Karak during the experimental period. About 25 (64.1%) of which belonged to arboreal plants and 14 (35.9%) to non arboreal taxa. Of these, 197,000 and 190,000 pollen grains were identified in 2005/2006 and 2006/2007, respectively. Of total pollen

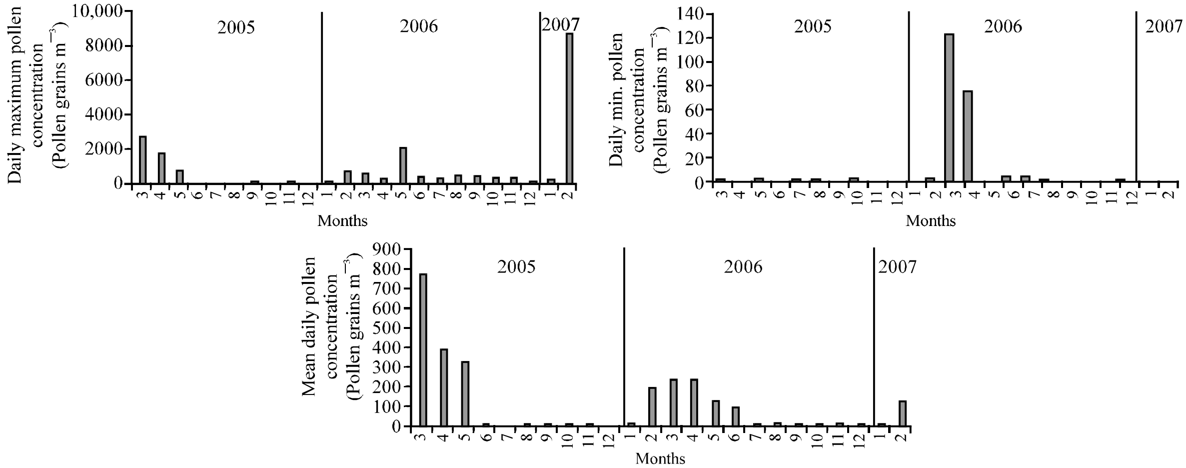

Fig. 4: Maximum, minimum and mean daily pollen grains concentration for the period March 2005 to February 2007. Numbers from 1-12 are representing months extending from January to December

Table 2: Annual totals of weekly pollen counts and percentages from February 2005-March 2007

Taxa	Mar.-Feb. 2005/2006	Mar.-Feb. 2006/2007	Total	Percent
Arboreal pollen grains				
Acer sp.	800	100	900	0.23
Acacia sp.	4700	2600	7300	1.89
Aesculus sp.	1800	200	2000	0.52
Arbutus sp.	3200	2100	5300	1.37
Calycotome sp.	1700	4300	6000	1.55
Citraceae	5800	2300	8100	2.09
Cupressus sp.	12000	9400	21400	5.53
Daphne sp.	1100	400	1500	0.39
Fraxinus sp.	1700	100	1800	0.47
Juglans sp.	1900	300	2200	0.57
Juniperus sp.	1100	3200	4300	1.11
Laurus sp.	1500	2700	4200	1.09
Lycium sp.	800	2200	3000	0.78
Moraceae sp.	2200	1100	3300	0.85
Olea sp.	6500	12300	18800	4.86
Pinus sp.	22100	19500	41600	10.75
Platanus sp.	2400	300	2700	0.70
Populus sp.	1200	600	1800	0.47
Quercus sp.	8700	12000	20700	5.35
Rhamnus sp.	1600	500	2100	0.54
Robinia sp.	400	900	1300	0.34
Rosaceae sp.	3200	5300	8500	2.20
Salix sp.	1200	2900	4100	1.06
Tamarix sp.	8600	7600	16200	4.19
Ziziphus sp.	3200	2100	5300	1.37
Total	99400	95000	194400	50.23
Non-Arboreal Pollen grains (NAP)				
Amaranthaceae	12600	11600	24200	6.25
Caryophyllaceae	1600	4800	6400	1.65
Chenopodiaceae	6400	11200	17600	4.55
Compositae	23600	11400	35000	9.04
Geraniaceae	1300	400	1700	0.44
Gramineae	15600	17600	33200	8.58
Malvaceae	2200	6300	8500	2.20
Origanum sp.	2900	700	3600	0.93
Papilionaceae	2300	4200	6500	1.68
Plantago sp.	2000	1100	3100	0.80
Rumex sp.	4200	3200	7400	1.91
Salvia sp.	600	1200	1800	0.47
Umbelliferae	1200	2300	3500	0.90
Urticaceae	8500	9200	17700	4.57
Total	85000	85200	170200	43.98
Unidentified	12600	9800	22400	5.79
Total	197000	190000	387000	100.00

grains in Karak's environment, 75.74% was found to be arboreal, 21.80% was non-arboreal and 5.79% of the total pollens were unidentified (Table 2). The major arboreal pollen producers in the atmosphere of Karak district were *Pinus* sp. (10.75%), *Cupressus* sp. (5.53%), *Quercus* sp. (5.35%), *Olea* sp. (4.86%), *Arbutus* sp. (1.37%), *Salix* sp. (1.06%), *Calycotome* sp. (1.55%), *Tamarix* sp. (4.19%), *Laurus* sp. (1.09%), *Juniperus* sp. (1.11%) and Citraceae (1.89%). Among non-arboreal plants, pollen grains belonging to Chenopodiaceae (4.55%), Gramineae (8.58%), Uticaceae (4.57%), Compositae (9.04%), Amaranthaceae (6.25%), Caryophyllaceae (1.65%) and Malvaceae (2.20%) showed the highest pollen dispersal. Monthly pollen variations in arboreal and non-arboreal plants in the atmosphere of Karak during the years 2005-2007 were detected. The earliest pollen releasing to Karak's atmosphere was noted in January (Table 3). In January, only pollen grains released from *Pinus* sp. and Amaranthaceae were recorded in very limited amounts. There was a slight increase in number of pollen grains in February; arboreal pollen grains of Gramineae, *Plantago*, Amaranthaceae, *Rumex* sp., *Salvia* sp., *Origanum* sp., Umbelliferae and Caryophyllaceae were observed during this month. Number of pollen grains started to increase in March and reached their maximum level in April. *Cupressus* sp., *Quercus* sp., *Olea* sp., *Arbutus* sp., *Salix* sp., *Calycotome* sp., Rosaceae, *Tamarix* sp., *Acacia* sp., Citraceae, Chenopodiacea, Gramineae, Urticaceae, Compositae, Amaranthaceae, *Rumex* sp., Malvaceae and Papilionaceae dispersed high amount of pollen into the Karak's atmosphere during their pollination periods and contributed >84% of the total grains in April. Number of pollen grains was still at high levels in May to July. Low quantities of pollen grains were recorded with the end of the pollination period (i.e., after July). *Pinus*

Table 3: The highest airborne pollen concentration in consecutive months and their yearly composition (%), Karak district, Jordan

Taxa	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total (%)
Acacia sp.	0.00	0.00	0.19	1.19	0.33	0.09	0.09	0.00	0.00	0.00	0.00	0.00	1.89
Acer sp.	0.00	0.00	0.04	0.09	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.23
Aesculus sp.	0.00	0.00	0.14	0.13	0.13	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.52
Amaranthaceae	0.40	2.00	1.45	2.05	0.26	0.04	0.00	0.00	0.00	0.00	0.00	0.05	6.25
Arbutus sp.	0.00	0.0	0.21	0.73	0.33	0.10	0.00	0.00	0.00	0.00	0.00	0.00	1.37
Calycotome sp.	0.00	0.00	0.22	0.75	0.38	0.10	0.10	0.00	0.00	0.00	0.00	0.00	1.55
Caryophyllaceae sp.	0.00	0.19	0.19	0.29	0.49	0.29	0.10	0.10	0.00	0.00	0.00	0.00	1.65
Chenopodiaceae	0.00	0.14	1.00	2.46	0.65	0.15	0.15	0.00	0.00	0.00	0.00	0.00	4.55
Citraceae	0.00	0.00	0.09	0.87	0.05	0.04	0.35	0.39	0.30	0.00	0.00	0.00	2.09
Compositae	0.00	1.15	2.29	4.09	0.75	0.34	0.34	0.04	0.04	0.00	0.00	0.00	9.04
Cupressus sp.	0.00	0.00	0.89	1.29	2.27	1.05	0.02	0.01	0.00	0.00	0.00	0.00	5.53
Daphne sp.	0.00	0.00	0.05	0.14	0.10	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.39
Fraxinus sp.	0.00	0.06	0.08	0.08	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.47
Geraniaceae	0.00	0.00	0.10	0.24	0.03	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.44
Gramineae,	0.00	0.51	0.79	3.14	2.23	1.44	0.47	0.00	0.00	0.00	0.00	0.00	8.58
Juglans sp.	0.00	0.00	0.10	0.19	0.15	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.57
Juniperus sp.	0.00	0.00	0.10	0.20	0.30	0.29	0.09	0.09	0.04	0.00	0.00	0.00	1.11
Laurus sp.	0.00	0.00	0.10	0.38	0.21	0.08	0.08	0.08	0.08	0.08	0.00	0.00	1.09
Lycium sp.	0.00	0.00	0.10	0.38	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.78
Malvaceae sp.	0.00	0.00	0.19	1.04	0.39	0.19	0.19	0.10	0.10	0.00	0.00	0.00	2.20
Moraceae sp.	0.00	0.00	0.00	0.21	0.51	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.85
Olea sp.	0.00	0.00	0.45	2.75	1.65	0.01	0.00	0.00	0.00	0.00	0.00	0.00	4.86
Origanum sp.	0.00	0.10	0.34	0.39	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.93
Papilionaceae	0.00	0.00	0.19	1.10	0.10	0.09	0.09	0.11	0.00	0.00	0.00	0.00	1.68
Pinus sp.	0.01	0.01	0.02	0.02	5.06	4.55	1.08	0.00	0.00	0.00	0.00	0.00	10.75
Plantago sp.	0.00	0.10	0.31	0.34	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.80
Platanus sp.	0.00	0.00	0.10	0.19	0.19	0.10	0.10	0.02	0.00	0.00	0.00	0.00	0.70
Populus sp.	0.00	0.00	0.08	0.19	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.47
Quercus sp.	0.00	0.00	0.49	2.34	1.85	0.64	0.02	0.01	0.00	0.00	0.00	0.00	5.35
Rhamnus sp.	0.00	0.00	0.09	0.25	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.54
Robinia sp.	0.00	0.00	0.00	0.05	0.10	0.10	0.04	0.05	0.00	0.00	0.00	0.00	0.34
Rosaceae	0.00	0.00	0.75	1.00	0.03	0.03	0.02	0.01	0.01	0.35	0.00	0.00	2.20
Rumex sp.	0.00	0.19	1.19	0.38	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.91
Salix sp.	0.00	0.00	0.01	1.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	1.06
Salvia sp.	0.00	0.07	0.07	0.23	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47
Tamarix sp.	0.00	0.00	1.10	1.90	0.99	0.05	0.05	0.01	0.01	0.08	0.00	0.00	4.19
Umbelliferae	0.00	0.13	0.19	0.29	0.19	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.90
Urticaceae	0.00	0.00	0.80	2.10	0.80	0.80	0.17	0.00	0.00	0.00	0.00	0.00	4.67
Ziziphus sp.	0.00	0.00	0.10	0.10	0.10	0.11	0.19	0.29	0.29	0.19	0.00	0.00	1.37
Unidentified	0.37	1.37	0.78	2.00	0.18	0.10	0.14	0.18	0.29	0.28	0.10	0.00	5.79
Total	0.78	6.02	15.38	36.56	21.49	11.67	4.27	1.62	1.21	0.98	0.10	0.05	100.00

sp. and *Cupressuss* sp., *Quercus* sp., *Olea* sp. and Gramineae are the major contributors to the pollen amount in May and June. The pollen grains of *Pinus* sp., Citraceae, Gramineae, Compositae had the most important contribution to the total pollen number in July. *Ziziphus* sp. and Citraceae were the major arboreal contributor to the pollen number in August and September. In November, a very limited amount of unidentified pollen grains were recorded (<1%) while in December only non-arboreal pollen types such as Amaranthaceae (0.05%) were recorded.

The results from this aerobiological study of pollen grains and spore dispersion were obtained from a single study area in Jordan. Therefore, these results of pollen dispersion may vary from a certain region to another and consequently not be applicable to other regions (Ribeiro *et al*., 2003). It is obvious from the results obtained that the maximum monthly pollen count was in spring (i.e., from March to May depending on the season) during the pollinosis period of the most trees, shrubs and other annual plants and the minimum monthly pollen count was in summer, autumn and first winter months (from June to January depending on the season) during the least pollinosis activity for the most vascular plants. Atmosphere concentration of different pollen types and a pollen calendar of populated areas are very important factors for allergological uses (Aytuo *et al*., 1990; Mullins and Emberlin, 1997; Docampo *et al*., 2007). It is well known that pollen grains of some plants are allergens for humans and correlated with increasing pollinosis that cause some respiratory system diseases. Therefore, determination of the type and concentration of pollen grains will be beneficial for patients suffering from allergic diseases (Mandrioli *et al*., 1982; D'Amato *et al*., 1983; Bousquet *et al*., 1984, 1986; D'Amato *et al*., 1998; Sin *et al*., 2001; D'Amato and Liccardi, 2003; Ture and Salkurt, 2005; Bicakci *et al*., 2005; Bicakci, 2006; Erkara, 2007). Therefore, pollinosis is correlated with phenology rather than weather and consequently, allergic diseases appear mainly during the flowering periods of plants

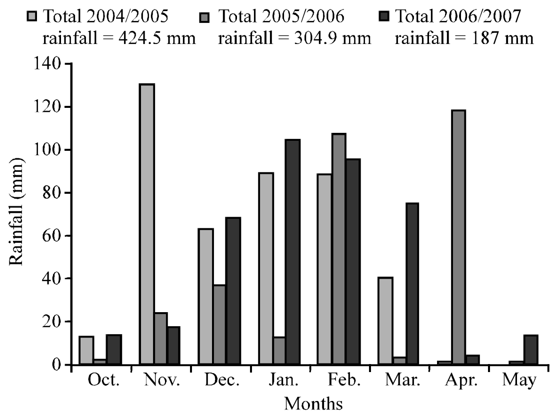

Fig. 5: Rainfall distribution in the study area during three successive rainfall seasons, 2004/2005, 2005/2006 and 2006/2007

which is in line with results obtained in previous studies (Corden and Millington, 1999; Emberlin *et al.*, 2002; Garcia-Mozo *et al.*, 2002).

Previous studies showed that atmosphere concentration of different pollen types varies enormously from one country to another in regions of the same country and even among different cities because pollen emissions depend on vegetation and environmental conditions (Frenguelli *et al.*, 1992; Dahl and Strandhede, 1996; Laaidi, 2001; Jato *et al.*, 2002; Ribeiro *et al.*, 2003). In the current study intra year and year to year variations in pollen counts were observed which is attributable not only to species diversity but also to weather conditions during the rainfall season (in Jordan from October to May). In 2005, the main pollen season was detected during March while in 2006 the highest pollen dispersal peak being recorded in April. This year to year variation in pollen dispersal is mainly due to the inter-seasonal variation in rainfall (Fig. 5) the period of pollinosis in 2006 was delayed because insufficient early rains were received in 2005/2006 rainfall season which delayed the time of pollinosis while sufficient rains was received in 2004/2005 which promote early spring occurrence. Moreover, 2005/2006 season was drier than 2004/2005 growing season (Seasonal rainfall = 424.5 and 304.9, respectively) therefore, pollen grain concentrations were higher in March to May 2005 than those in 2006. In 2007, the pollen grain concentrations during January and February were higher than those of 2006 since 2006/2007 season was the driest (Seasonal rainfall = 187 mm) indicating also inter-seasonal variation in pollen grain concentration.

Intradiurnal variations in pollen counts, the highest counts were observed between 8.00-2.00 pm because the maximum level of anther extrusion and pollens dispersal is occurred in the midday. According to previous studies (Galan *et al.*, 1991; Rodriguez-Rajo *et al.*, 2005) intradiurnal variations in pollen counts proved to be present. Mediterranean areas (Galan *et al.*, 1991) also display an irregular pattern, with several peaks throughout the day.

High levels of monthly total counts of pollen grains appear mainly during the flowering periods therefore, results obtained in this study are due mainly to spring flowering period between March and May which tended to coincide with high air pollen grain dispersals. It was observed also that the total pollen grain counts was low during summer because it is dry and most plant species are out of flowering period although, certain plant families pollinate during summer like Amaranthaceae, Chenopodiaceae, Cistaceae, Papaveraceae (Faegari and Iversen, 1975; Al-Eisawi, 1982; Karim and Al-Quran, 1988; Huysmans, 1998; Dessein *et al.*, 2000; Al-Quran, 2004a, b).

Dominancy of arboreal pollen types in Karak's environment is the character of the vegetation and the geographical location of the study area (Table 2). *Pinus* sp., *Cupressus* sp., *Quercus* sp., *Olea* sp., *Arbutus* sp., *Salix* sp., *Calycotome* sp., *Tamarix* sp., *Laurus* sp., *Juniperus* sp. and Citraceae were frequently found arboreal pollen types. Chenopodiaceae, Gramineae, Uticaceae, Compositae, Amaranthaceae, Caryophyllaceae and Malvaceae were among the major non-arboreal contributors to the total pollen grains in the atmosphere of Karak. The major pollen producers in the atmosphere of karak were arboreal plants comprising about 64.1% of the total taxa identified. According to other studies carried out in other parts in the world, arboreal pollen type were also dominant: 80% in Ankara (Pynar *et al.*, 1999), 69.7% in Thessaloniki, Greece (Damialis *et al.*, 2005), 82.0% in Finland (Koivikko *et al.*, 1986), 55.0% in Ascoli Piceno, Italy (Romano *et al.*, 1988) and 73.0% in Poland (Kasprzyk,1996).

Some weeds, certain trees and grasses produce pollen which is widely distributed by air and cause symptoms in susceptible patients. Its relative contribution to pollinosis varies regionally in relation to local vegetation type, agriculture and climate (Spieksma, 1990; Docampo *et al.*, 2007). This investigation shows that some allergenic pollen, float in the air throughout the whole the year with inter-monthly variations of total pollen grains dispersal (Table 3). This result may be of great importance to allergic individuals and allergology (D'Amato and Spieksma, 1990, 1992; Armentia *et al.*, 2004; Rodriguez *et al.*, 2007). Some important allergic pollens which found in high concentrations in Karak atmosphere were *Pinus* sp. (Freeman, 1993; Marcos *et al.*, 2001), *Cupressus* sp. (Leventin and Buck, 1980; Bousquet *et al.*, 1984; Spieksma, 1990), *Quercus* sp. (Eriksson *et al.*, 1984; Zawisza and S-Zawisza, 1991; Weryszko-Chmielewska *et al.*, 2006), *Olea* sp., (Guvensen and Ozturk, 2002; Ture and Bocuk, 2009), *Salix* sp. (Ince, 1994), Urticaceae (Bousquet *et al.*, 1984; Wallin *et al.*, 1991), *Calycotome* (Lewis and Vinay, 1979; Aytug *et al.*, 1990), Moraceae (Aytug *et al.*, 1990), Rosaceae (Ture and Bocuk, 2009), Chenopodiaceae/ Amaranthaceae (Leventin and Buck, 1980; Colas *et al.*, 2005), Gramineae (Chapman, 1986), *Plantago* sp. (Chapman and Williams, 1984) and *Rumex* sp. (Guvensen and Ozturk, 2002; Ture and Bocuk, 2009). Pollen produced by grasses (Graminae) such as *Lolium perenne*, *Poa pratensis*, *Dactylis glomerata*, *Hordeum* sp. and *Avena* sp. is the major cause of pollinosis (Pollen allergy) in many parts of the world (Chapman, 1986). In the olive tree family the most allergenic pollen is produced by *Olea europaea* which frequently seen in Karak district. In the Mediterranean area, the olive pollen has been recognized as one of the most important causes of seasonal respiratory allergy. The olive pollination season lasts from April to late June and can causes severe symptoms in people allergic to its pollen. Frequently, sensitization to olive tree pollen is associated with other allergies such as grass pollen (Soldevilla *et al.*, 1995; Rahal *et al.*, 2007). It is noticed that the pollen grains from herbs like *Plantago*, *Fraxinus* and compositae are of limited quantities but nevertheless with real clinical importance (Koivikko *et al.*, 1986; Jager *et al.*, 1991; Rodriguez-Rajo *et al.*, 2005; Rahal *et al.*, 2007).

Separation of different pollen species of vegetation flowering at different times of the year and correlate them with pollen grains of some plant species that are allergens for humans are very important (Aytuo *et al.*, 1990; Mullins and Emberlin, 1997; Docampo *et al.*, 2007). Therefore, a pollen-monitoring network is in demand in Jordan. Such network would lead to establish pollination calendars that can highly aid allergy or asthma patients and physicians in determining correlations between particular aerial pollen type concentrations and seasonal allergic symptoms. Levels of the majority of allergic pollen types peaked in March to May which are usually the worst times of the year for people allergic to pollen in Karak.

CONCLUSION

In this study, the results showed that some plant taxa, namely; *Pinus* sp. *Cupressus* sp., *Quercus* sp., *Olea* sp., *Salix* sp., Urticaceae, Calycotome, Moraceae, Rosaceae, Chenopodiaceae/Amaranthaceae, Gramineae, *Plantago* sp. and *Rumex* sp. has a clinical correlation with the specific pollen allergens in Karak district.

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