# Relationship Between Weather Conditions and Release of Allergen Pollen and Spores to the Air in Haifa

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*Daily airborne pollen and fungal spores were collected over one year (1.2.06 – 31.1.07), using a Burkard continuous volumetric pollen trap, located in the center of a neighborhood in Haifa. Twenty one allergenic pollen types and twenty four spore types were identified. Daily records of seven main meteorological factors (rainfall, sunshine, main wind direction, wind speed, air temperature, relative humidity and barometric pressure) were gathered too. The aim of the present study is to determine the main pollination/sporulation seasons (MPS)/(MSS), the peak periods (PP), and specific days (SD) for each type of pollen and spores identified, and to find correlations with meteorological factors. The 21 pollen types were divided into five groups according to main pollination season. Spore types were divided into four groups according to their main sporulation season. Positive correlation was found between pollen and spore concentration and mean temperature. Negative correlations were found between pollen concentration and relative humidity and between spore concentration and barometric pressure.*

***Keywords:*** *Airborne pollen, fungal spores, meteorological parameters, allergy, Haifa.*

Every year at spring and autumn, thousands of people in Israel and in other countries suffer from sneezing, rhinitis, scraping in the nose and bronchial asthma. This phenomenon is called "hay fever", and it is estimated that the allergic population rate ranges between 15%–20%.

The relationship between pollen and spores and weather conditions was studied in many areas. In Kfar-Saba (Israel), a positive correlation between temperature and pollen concentration, and a negative correlation between pollen concentration and rainfall or relative humidity, were found. During *khamsin* conditions (very hot and dry weather), the pollen concentration was higher (Keinan, 1986). Similar correlations were found also in Lugo, Spain (Rodriguez-Rajo et al., 2003), Braga, Portugal (Riberio et al., 2003) and Thessaloniki, Greece (Gioulekas et al, 2004). In Sydney,

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Australia, high pollen concentration during the warm months were found to be influenced by a region of low surface pressure located to the south of the continent, bringing fast dry westerly gradient winds to Sydney (Hart, et al., 2006).

The relationships between weather parameters and airborne pollen of *Pinus* in Brisbane, Australia, shows that the onset of the *Pinus* pollen season coincided with the coolest average monthly temperature (<22ºC), lowest rainfall (<7 mm), and four weeks after daily minimum temperature fell to 5–9ºC in the late autumn. Negative correlation coefficients were obtained between daily airborne *Pinus* pollen counts with maximum temperature ($p<0.0001$), minimum temperature ($p<0.0001$) and rainfall ($p<0.05$) during the main pollination period (Green, et al., 2003).

Fungi are known to be ubiquitous in nature, growing where organic material is available. The release of fungal spores, and consequently their concentration in the atmosphere are the result of many biological and environmental factors. In Cracow, Poland, fungal spores were present in the air in large numbers throughout the summer, reaching the highest levels in June and August, although their highest concentration varies with time. For most of the studied spore types—*Botryis, Ganoderma, Alternaria, Epicoccum, Torula, Drechslera type, Polythrincium, Stemphylium and Pithomyces*, the peak period was recorded in August. *Didymella* and *Entomophthora* spores reached their highest concentrations in July, while the concentration of *Erysiphales* and *Cladosporium* spores was highest in June. Multiple regression analysis between spores and temperature were performed for two seasonal periods: pre-peak and post peak. In the pre-peak period, the concentration of 10 spore type—*Cladosporium*, *Botrytis*, *Epiciccum*, *Stemphylium*, *Drechslera* type, *Pithomyces*, *Didymella*, *Erysiphsles*, *Ganoderma* and *Entomophthora* were influenced mostly by minimum temperature, while *Alternaria, Polythrincium* and *Torula* were influenced by maximum temperature. During the post-peak period, the most important factor affecting variation of concentration of *Botrytist*, *Polythrincium*, *Didymella*, *Erysiphsles*, *Ganoderma* and *Entomophthora* spores was the minimum temperature. For *Alternaria*, *Cladosporium, Epicoccum* and *Torula,* the maximum temperature appeared to be most influential, whereas for *Drechslera* type, *Stemphylium* and *Pithomyces*, it was sunshine (Stepalska and Wolek, 2005).

*Allternaria* is a familiar aeroallergen, being a risk factor in childhood and adult asthma. A comparison of 1970-1996 daily records of *Allternaria* spores between Cardiff and Derby in the UK was carried by Corden et al. (2003). On certain days in recent years, Derby *Allternaria* spore counts have exceeded 1000 spores per $m^2$ of air, while in Cardiff such high counts have not occurred since 1970. Derby *Allternaria* spore levels were most positively correlated with south-east winds (over large stretches of arable land), and together with higher midsummer temperature they could account for the rising *Allternaria* counts, whereas in Cardiff the coastal position, together with the small amount of arable land, ensure that the level of *Allternaria* spore remains low (Corden et al., 2003).

The aim of the present study is to determine different definitions of the main season of pollen and spores and to relate them to meteorological conditions in Haifa, Northern Israel.

## DATA AND METHODS

Haifa is situated on the Israeli Mediterranean Coastal Plain, located on the northern slopes of Mount Carmel and around Haifa Bay. Its geographical location is 32°49'0'' N 34°59'0'' E. Haifa is the largest city in northern Israel, and the third largest city in the country, with a population of over 265,000 (2008).

### *Pollen and Spore Monitoring*

Daily sampling of airborne pollen and spores was performed for one year (from February, 1 2006 till January, 31 2007). Airborne pollen grains and spore concentrations were measured by a 7 day continuous recording *Burkard* volumetric pollen trap, an instrument widely used for aerobiological sampling (Rantio-Lehtimaki, 1991). The trap was placed on the roof of a three-floor building in one of the centers of the Neve Sha'anan neighborhood, elevated 12m above ground level and 205m a.s.l. The *Burkard* trap is a compact unit with a built-in vacuum pump, designed to sample airborne particles, such as pollen grains and spores, continuously for a period of up to 7 days without any need for human intervention, and it is supported by a clock work driven drum. The drum completes rotation within one week, and then the tape is taken out and cut into seven equal sections, each representing a single day of the sampling (i.e. 48mm tape). These were mounted on slides with glycerin and saffranine under cover-slips. The identification and counting of pollen grains and spores was performed under a light microscope. Pollen and spore concentration was measured as the daily number of pollen grains and spores per a cubic meter of air (Rantio-Lehtimaki, 1991).

Pollen of the following plant taxa were included in the study: *Cupressus, Pinaceae*, *Fagaceae*, *Parietaria/Urticaceae*, *Eucalyptus*, *Olea*, *Pistacia*, *Phillyrea*, *Poaceae*, *Urticaceae*, *Mercurialis*, *Chenopodiaceae*, *Arecaceae*, *Morus*, *Artemisia*, *Fabaceae*, *Brassicaceae*, *Umbelliferae*, *Maclura*, *Carya*, and *Asteraceae*.

The presence of spores of 24 taxa was detected as follows: *Cladosporium, Ascospora, Periconia, Johnson grass smut, Alternaria, Oidium, Coprinus, Bipolaris, Ganoderma, Arthinrium, Myxomicete, Agaricus, Rust, Perenospora, Nigrospora, Stemphylium, Agrocybe, Chaetomium, Epicoccum, Torula, Circinotrichum, Basidiospores, Neohendersonia Kickxii and Belthrania.*

### *Meteorological Variables*

The recorded meteorological variables were daily rainfall amount (mm), total daily solar radiation ($W/m^{-2}$), mean daily air temperature (°C), mean daily relative

humidity (%), mean daily wind speed (m/s), and mean daily barometric pressure (hPa). All daily means were calculated based on half an hour measurements, i.e. average of 48 values measured at a meteorological station on the same roof where the volumetric pollen trap was installed.

### *Statistical Analysis*

Daily pollen/spore counts for one year were summed and averaged for each month. In order to define the main pollination/sporulation season, the period covering 95% or 90% (depending on pollination/sporulation characteristics) of total annual pollen was considered, thus omitting the periods in which the first and last 2.5% (or 5%) were obtained. This methodology was proposed by Galan et al., (1991).

For each plant and spore monthly means and standard deviations were calculated. The *peak period* (**PP** hereafter) was defined as the time elapsed between the first and the last day that pollen and spore concentrations were higher than one or two standard deviations (depending on seasonal characteristics). Specific days (**SD** hereafter) for each plant and spore were determined according to days of very high concentration, higher than two standard deviations, which were not continuous.

The relationship between daily pollen and/or spore count, and meteorological variables were analyzed for each pollen and spore in the main pollination/sporulation season (**MPS**)/(**MSS**), using regression and Spearman tests. Simple regressions were calculated between each of the four meteorological variables: air temperature, relative humidity, atmospheric pressure and solar radiation with pollen/spore concentrations for both the **PP** and the **SD** (defined as no lag). In addition, simple regressions were calculated between the pollen/spore concentrations and the four aforementioned meteorological variables on the previous day (defined as Day-1) (Tables 1 and 2).

## RESULTS AND DISCUSSION

In total, 23,340 pollen grains were identified and counted from 21 plant species, which were distributed as follows: *Cupressus* accounted for 39.6% of the overall pollen grains, *Pinaceae* – 21.1%, *Fagaceae* – 11.4%, *Parietaria*/*Urticaceae* – 5.7%, *Eucalyptus* – 5.6%, *Olea* – 5%, *Pistacia* – 2.7%, *Phillyrea* – 2.6%, *Poaceae* – 1.8%, *Urticaceae* – 1.3%, *Mercurialis* – 1%, *Chenopodiaceae* – 0.6%, *Arecaceae* – 0.3%, *Morus* – 0.3%, *Artemisia* – 0.2%, *Fabaceae* – 0.2%, *Brassicaceae* – 0.1%, *Umbelliferae* – 0.1%, *Maclura* – 0.1%, *Carya* – 0.1% and *Asteraceae* – 0.1% (Figure 1).

**Table 1:** Regression analysis between daily average polen values and four meteorological factors in the peak period. No lag means simultaneous regressions. Day-1 means regression between polen values and the meteorological factors of the previous day.

| Single regression analysis | Temperature | | Relative humidity | | Atmospheric pressure | | Sunshine | |
|---|---|---|---|---|---|---|---|---|
| | No lag | Day-1 | No lag | Day-1 | No lag | Day-1 | No lag | Day-1 |
| *Arecaceae (26.5.06-4.8.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Artemisia (20.10.06-24.11.06)* | n.s. | n.s. | -0.46** | -0.41* | n.s. | n.s. | n.s. | n.s. |
| *Brassicaceae (6.3.06-22.4.06)* | n.s. | n.s. | n.s. | -0.29* | -0.34* | n.s. | n.s. | n.s. |
| *Chenopodiaceae (27.7.06-24.11.06)* | 0.37** | 0.25** | n.s. | n.s. | -0.22* | -0.19* | 0.22* | 0.23* |
| *Cupressaceae (12.3.06-22.3.06)* | 0.62* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Eucalyptus (23.4.06-21.6.06)* | 0.36** | 0.36** | -0.41** | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Fabaceae (19.6.06-4.7.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Fagaceae (23.3.06-20.4.06)* | n.s. | n.s. | -0.39* | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Mercurialis (18.2.06-22.3.06)* | n.s. | n.s. | -0.40* | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Moraceae (23.3.06-8.4.06)* | 0.71** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Myrica (26.5.06-19.6.06)* | 0.39* | n.s. | n.s. | n.s. | -0.41* | n.s. | n.s. | n.s. |
| *Olea (20.4.06-7.5.06)* | 0.77** | n.s. | -0.67** | -0.57* | n.s. | n.s. | n.s. | n.s. |
| *Parietaria (23.3.06-30.5.06)* | 0.31** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Phillyrea* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Pinaceae (12.3.06-23.3.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Pistacia* | 0.52* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Poaceae (8.4.06-21.6.06)* | 0.37** | 0.25* | n.s. | n.s. | n.s. | n.s. | n.s. | 0.26* |
| *Umbelliferae (8.4.06-11.6.06)* | n.s. | n.s. | -0.29* | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Urticaceae (13.2.06-5.4.06)* | n.s. | n.s. | -0.34* | n.s. | n.s. | 0.27* | n.s. | n.s. |

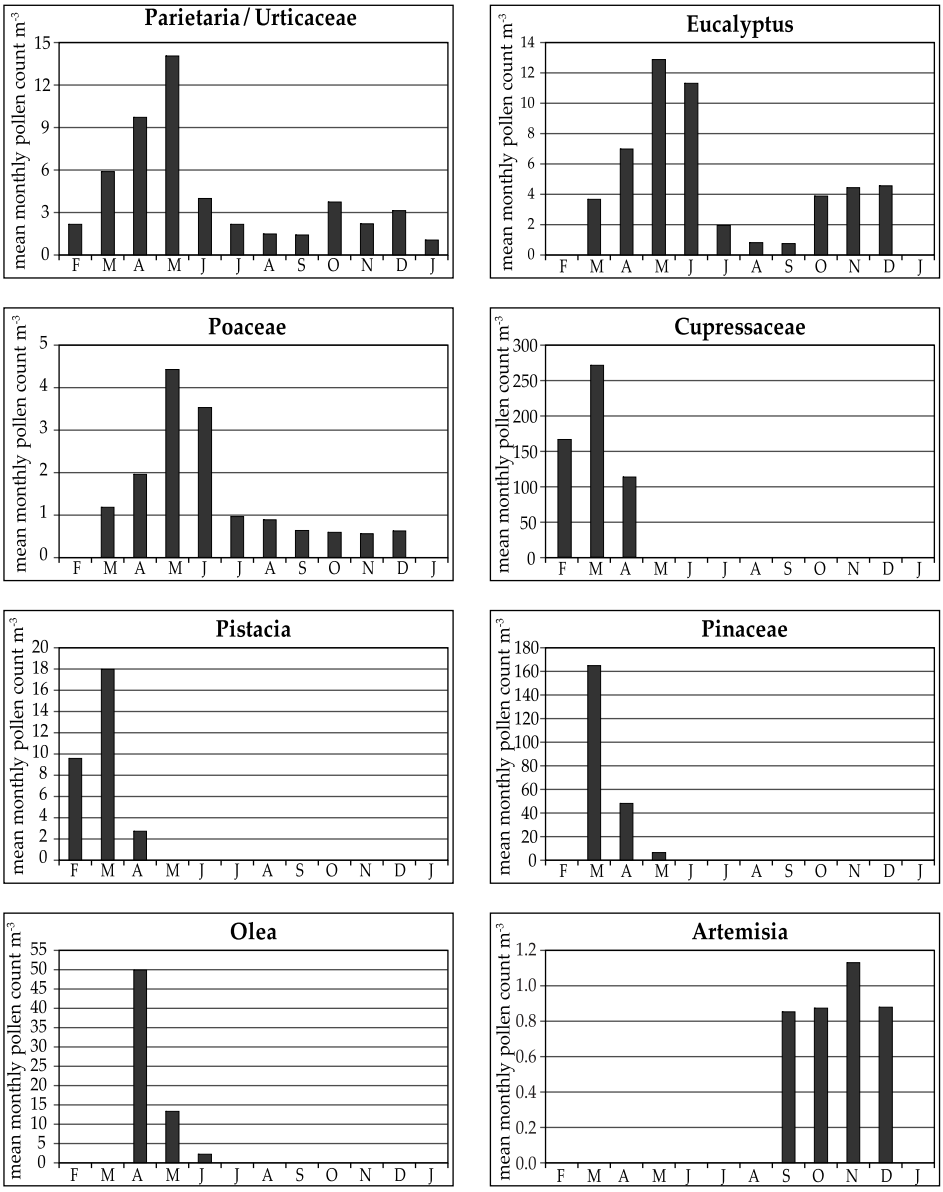
**$p<0.01$, *$0.01<p<0.05$, n.s. not significant ($p>0.05$)

**Table 2:** Regression analysis between daily average spore values and four meteorological factors in the peak period. No lag means simultaneous regressions. Day-1 means regression between spores values and the meteorological factors of the previous day.

| Single regression analysis | Temperature | | Relative humidity | | Atmospheric pressure | | Sunshine | |
|---|---|---|---|---|---|---|---|---|
| | No lag | Day-1 | No lag | Day-1 | No lag | Day-1 | No lag | Day-1 |
| *Agaricus (30.1.06-15.6.06)* | n.s. | -0.19* | -0.19* | n.s. | n.s. | 0.22** | n.s. | n.s. |
| *Agrocybe (31.1.06-18.2.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Alternaria (8.4.06-11.6.06)* | 0.29* | n.s. | -0.53** | n.s. | n.s. | n.s. | -0.24* | n.s. |
| *Ascospore (3.4.06-1.8.06)* | 0.26** | 0.23* | n.s. | n.s. | -0.33** | -0.20* | n.s. | n.s. |
| *Basidiospores (31.1.06-24.2.06)* | n.s. | n.s. | n.s. | n.s. | 0.40** | 0.43* | 0.39* | n.s. |
| *Belterania (21.2.06-20.6.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Bipolaris (23.3.06-15.7.06)* | n.s. | n.s. | -0.38** | n.s. | n.s. | 0.26** | n.s. | n.s. |
| *Circinotrichum (9.2.06-22.6.06)* | n.s. | n.s. | 0.22* | 0.18* | n.s. | n.s. | n.s. | n.s. |
| *Circinotrichum (2.10.06-23.1.07)* | 0.20* | n.s. | 0.28** | 0.22* | -0.27** | n.s. | 0.20* | n.s. |
| *Cladosporium (1.4.06-11.6.06)* | n.s. | -0.04 | -0.39** | n.s. | n.s. | 0.27* | n.s. | n.s. |
| *Coprinus (12.2.06-28.4.06)* | n.s. | -0.30** | n.s. | n.s. | 0.39** | 0.36** | n.s. | n.s. |
| *Coprinus (22.10.06-9.11.06)* | -0.50* | -0.49* | n.s. | n.s. | n.s. | n.s. | n.s. | -0.67** |
| *Epicoccum (21.5.06-1.11.06)* | n.s. | n.s. | n.s. | n.s. | -0.23** | -0.24** | 0.16* | 0.18* |
| *Ganoderma (18.6.06-15.11.06)* | -0.27** | -0.22** | n.s. | n.s. | 0.17* | n.s. | -0.24** | -0.27** |
| *Johnson Grass Smut (9.4.06-19.6.06)* | 0.28* | n.s. | n.s. | n.s. | -0.38** | -0.37** | n.s. | n.s. |
| *Myxomicete (2.11.06-19.12.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | 0.04ns | 0.06ns | -0.17ns |
| *Nigrospora (8.9.06-7.11.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Oidium (18.2.06-11.6.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Periconia (22.2.06-2.8.06)* | 0.37** | 0.33** | n.s. | n.s. | -0.24** | -0.20* | 0.24** | 0.30** |
| *Rust (18.4.06-19.6.06)* | n.s. | n.s. | -0.33** | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Rust (27.11.06-6.12.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | 0.54* | -0.48* |
| *Stemphylium (18.2.06-20.4.06)* | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| *Stemphylium (25.5.06-4.7.06)* | 0.47** | n.s. | n.s. | 0.35* | -0.45** | -0.44* | n.s. | -0.03 |
| *Stemphylium (5.10.06-14.12.06)* | 0.42** | 0.27* | 0.23* | 0.41** | -0.35** | 0.30* | 0.42** | 0.48** |

**p<0.01, *0.01<p<0.05, n.s. not significant (p>0.05)

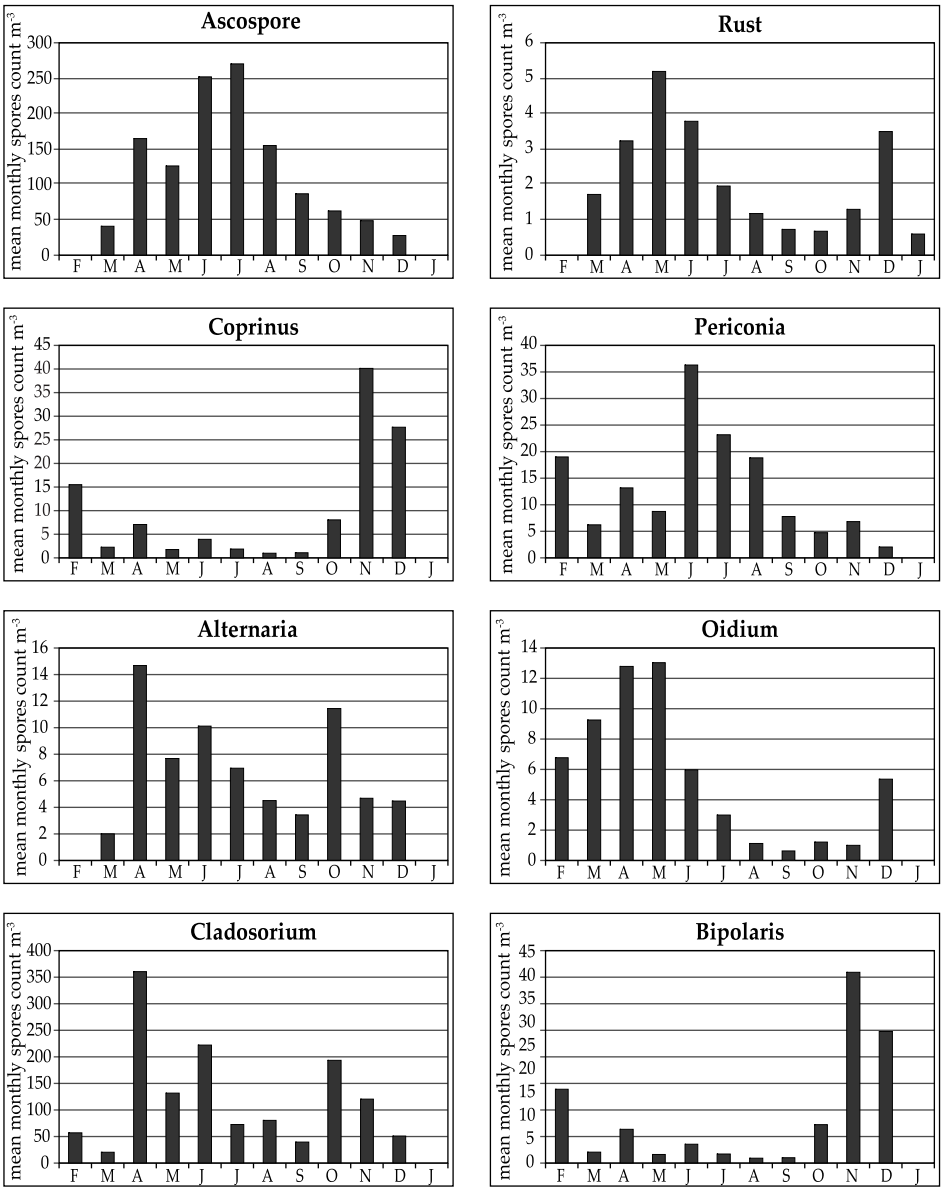
**Figure 1:** Monthly average of pollen concentration [$m^{-3}$]




In total, 86,970 spores were identified and counted from 24 different spore species, which were distributed as follows: *Cladosporium* accounted for 42.3% of the overall spores, *Ascospora* 39.1%, *Periconia* 4.1%, *Johnson grass smut* 1.3%, *Alternaria* 3.3%, *Oidium* 1.9%, *Coprinus* 1.8%, *Bipolaris* 1.6%, *Ganoderma* 1.3%, *Arthinrium* 1.0%, *Myxomicete* 1.0%, *Agaricus* 0.7%, *Rust* 0.6%, *Perenospora* 5%, *Nigrospora*

0.4%, *Stemphylium* 0.4%, *Agrocybe* 0.4%, *Chaetomium* 0.2%, *Epicoccum* 0.1%, *Torula* 0.1%, *Circinotrichum* 0.1%, *Basidiospores* 0.1%, *Neohendersonia Kickxii* 0.1%, *Belthrania* 0.03% (Figure 2).

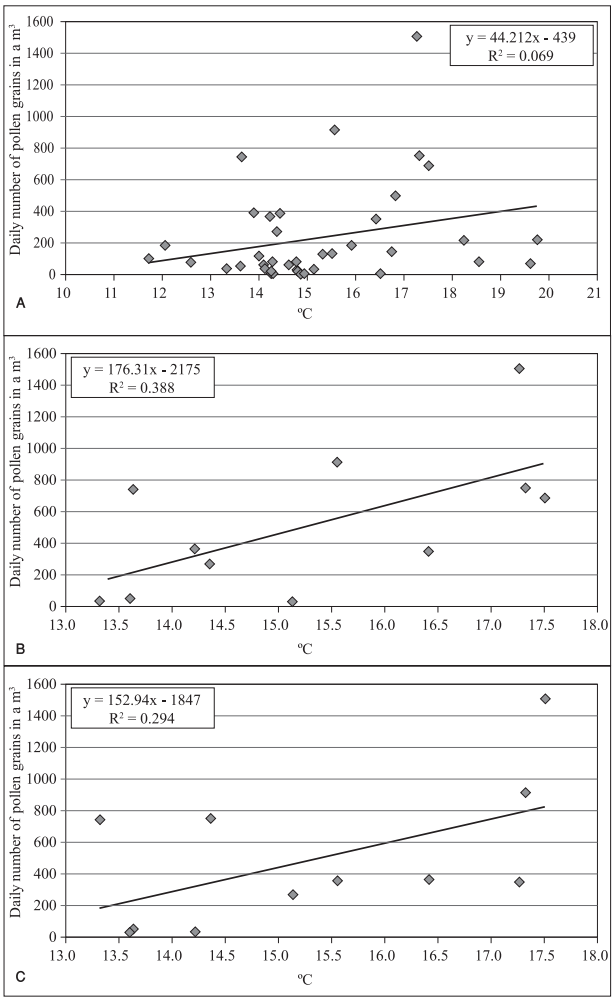
**Figure 2:** Monthly average of spore concentration [$m^{-3}$]



The following results of the present study are presented below, divided into three categories and summarized as follows:

### *Main Pollination/Sporulation Season of Plants/Spores (MPS /MSS)*

**Figure 3:** Regression between pollen concentration of Cupressaceae and temperature at the **MPS** (a), **PP** (b) and DAY-1 (c).

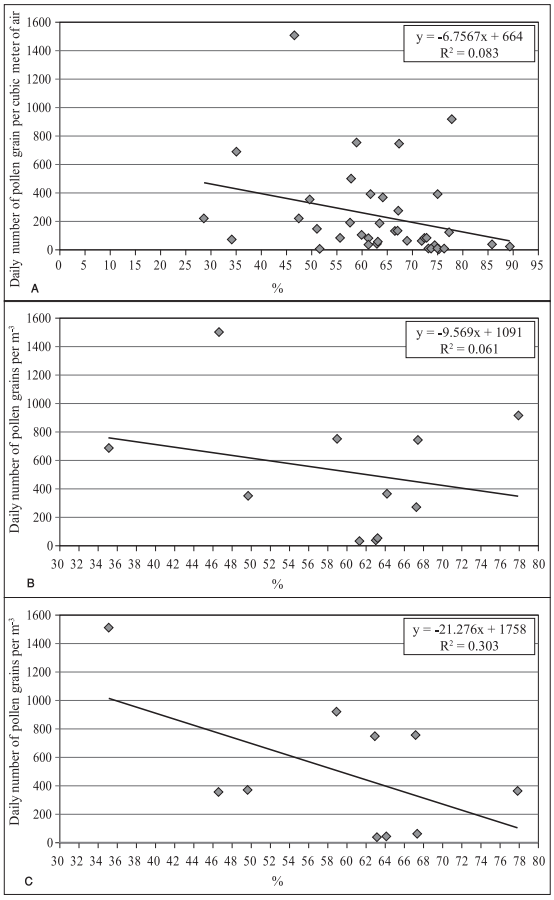



1. Temperatures higher than the seasonal average (in parentheses), or rising temperature, affected pollen grain release to the atmosphere in 13 out of the 21 plant species studied, and in 11 out of 24 spore species: *Parietaria*/*Urticaceae* (19.4°C), *Arecaceae* (21.2°C), *Chenopodiaceae* (21.1°C), *Poaceae* (21.4°C), *Eucalyptus* (21.0°C), *Artemisia* (20.6°C), *Pinaceae* (16.7°C),

*Mercurialis* (15.8°C), *Fagaceae* (17.6°C), *Urticaceae* (15.6°C), *Olea* (20.7°C) *and Maclura* (21.0°C). *Ascospora* (21.1°C), *Epicoccum (*22.3°C), *Bipolaris* (21.5°C), *Cladosporium* (20.8°C), *Chaetomium* (20.4°C), *Nigrospora* (20.4°C), *Belthrania* (20.7°C), *Rust* (19.9°C), *Johnson grass smut* (22.4°C), *Stemphylium* (20.5°C) and *Cupressaceae* (15.2°C). Figure 3A shows that the **MPS** of *Cupressaceae,* for example, was defined between 23.2.06–9.4.06, when temperatures increased as a result of seasonal warming. In other words, as long as the temperature increases, the pollen concentration increases too. Only in one observation, during the **MPS** of the *Cupressaceae,* the temperature was below average.

2. In *Alternaria* (21.0°C), for example, (Figure 5A), the **MSS** period continues for almost all year long, therefore, the mean temperature is higher than the mean temperature of other flowers where their **MPS** lasts for only few months. Although the $R^2$ is low, it still shows a positive correlation between temperature and *Alternaria*. The high *Alternaria* concentrations are obtained when temperatures are between 20°C - 24°C.
3. Below mean seasonal relative humidity (in parenthesis), or when it decreases, pollen grain release to the atmosphere is enhanced in 13 species out of the 21 studied plants and 5 spore species out of the 24 species: *Parietarial Urticaceae* (64%), *Chenopodiaceae* (65%), *Poaceae* (65%), *Eucalyptus* (64%), *Artemisia* (58%), *Pinaceae* (66%), *Pistacia* (65 *Mercurialis* (65%), *Fagaceae* (67%), *Olea* (67%), *Maclura* (67%) and *Umbelliferae* (67%), (65%), *Chaetomium* (64%), *Cladosporium* (64%), *Bipolaris* (68%), *Oidium* (64%), *Alternaria* (65%) and *Cupressaceae* (64%). Figure 4A shows that during **MPS**, as long as the relative humidity decreases, the *Cupressaceae* concentration remains high. However, in three different cases the *Cupressaceae* concentration remained high even though the relative humidity was high.
4. Below mean seasonal atmospheric pressure (in parenthesis) or when it decreases, spore release to the atmosphere is enhanced in 7 out of the 24 spore species studied: *Alternaria* (971.8 hPa), *Johnson grass smut* (970.6 hPa), *Ascospora* (971.6 hPa), *Epicoccum* (970.8 hPa), *Cladosporium* (972.0 hPa), *Periconia* (971.9 hPa), *Rust* (972.6 hPa) and *Nigrospora* (972.2 hPa).
5. In 11 plants, combined condition of high temperature and low relative humidity resulted in pollen grains released to the atmosphere of *Parietarial Urticaceae*, *Chenopodiaceae*, *Poaceae*, *Eucalyptus*, *Artemisia*, *Pinaceae*, *Cupressaceae*, *Mercurialis, Fagaceae*, *Olea* and *Maclura.*
6. In 7 spore species a combination of high temperature and low atmospheric pressure resulted in a release to the atmosphere of *Alternaria*, *Ascospora*, *Cladosporium*, *Epicoccum, Johnson grass smut Nigrospora* and *Rust*.

**Figure 4:** Regression between pollen concentration of Cupressaceae and the relative humidity at the **MPS** (a), **PP** (b) and DAY-1 (c).




***Peak Period (PP)***

7. A rise of the temperature, or a temperature higher than the **PP** mean temperature and/or the day before during the **PP**, affected the release of pollen grains and spores to the atmosphere in 11 out of 21 studied plant species and 6 of 24 spore species: *Parietaria/Urticaceae* (18.3°C), *Arecaceae* (24.1°C), *Chenopodiaceae* (23.0°C), *Poaceae* (20.4°C), *Eucalyptus* (19.6°C), *Pinaceae* (17.4°C), *Pistacia* (14.9°C), *Moraceae* (15.7°C), *Olea* (18.8°C), *Maclura* (23.1°C) and *Cupressaceae* (15.3°C). Figures 3A– 3C show that the range of temperature at the **PP** is smaller than the range at the **MPS**. In addition, the $R^2$ of both **PP**s (no lag and Day -1) are higher than the $R^2$ of the **MPS**. *Stemphylium* (19.2°C), *Periconia* (20.0°C), *Johnson grass smut* (20.3°C), *Ascospora* (21.6°C), *Circinotrichum* (17.1°C) and *Alternaria* (21.7°C). Figure 5B shows that the temperature range of **PP** is smaller than the temperature

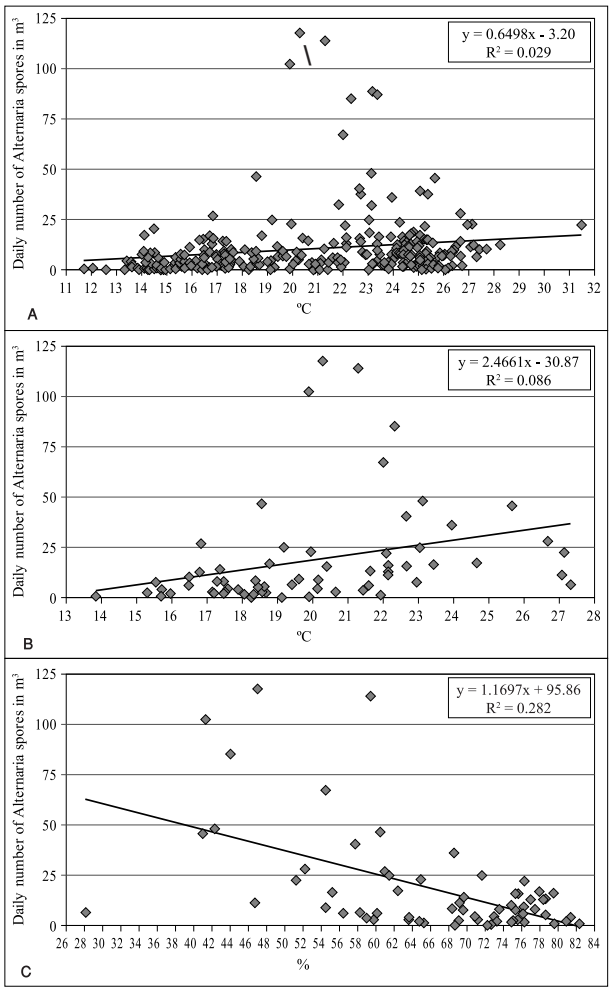
range of the **MSS**. The $R^2$ at the **PP** is higher than the $R^2$ at the **MSS**. In addition, the higher concentrations are around 20°C-22°C.

8. When relative humidity was lower than, or decreasing below the **PP** mean and/or the day before, it affected pollen grains and spore release in 9 out of the 21 studied plants, and 5 spore species: *Arecaceae* (70%), *Eucalyptus* (60%), *Artemisia* (62%), *Mercurialis* (60%), *Fagaceae* (69%), *Urtica* (64%), *Olea* (64%), *Brassicaceae* (65%) *and Umbelliferae* (66%). *Cladosporium* (67%), *Bipolaris* (68%), *Rust* (51%), *Agaricus* (65%) and *Alternaria* (64%). Figure 5C shows that the explained variance ($R^2$) by relative humidity is much higher than that explained by temperature, meaning that during **PP** the effect of relative humidity on Alternaria spore concentrations is higher than the effect of temperature.
9. When atmospheric pressure was lower than the **PP**, or decreased below its average value and/or atmospheric pressure of the following day was lower than that of the previous day, it enhanced spore species release in 7 out of 24 species studied: *Stemphylium* (973.4 hPa), *Johnson grass smut* (972.9 hPa), *Ascospora* (971.2 hPa), *Circinotrichum* (974.9 hPa), *Periconia* (972.3 hPa), *Epicoccum* (969.6 hPa).
10. When atmospheric pressure was higher than the **PP,** or increased above its average value and/or atmospheric pressure of the following day was higher than that of the previous day, it enhanced spore release in 6 of 24 spore species: *Basidiospores* (976.1 hPa), *Coprinus* (973.6 hPa), *Cladosporium* (972.8 hPa), *Bipolaris* (972.1 hPa), *Agaricus* (974.3 hPa), *Ganoderma* (969.5 hPa).
11. A rise of the solar radiation or a higher solar radiation above the average **PP** and/or the solar radiation of the following day was higher than that of the previous day before or during *peak period*, it enhanced the release of pollen grains and spores to the atmosphere in 6 spore species: *Basidiospores* (9232 $W/m^{-2}$), *Circinotrichum* (11421 $W/m^{-2}$), *Epicoccum* (17917 $W/m^{-2}$), *Periconia* (18234 $W/m^{-2}$) , *Stemphylium* (14326 $W/m^{-2}$), *Rust* (12731 $W/m^{-2}$).

***Specific Days (SD)***

12. High temperature and a rise of the temperature, as compared to the previous day, affected pollen grain release to the atmosphere in 9 out of the 21 plant species studied*: Moraceae* (16.4°C), *Poaceae* (19.6°C), *Chenopodiaceae* (21.3°C), *Olea* (19.0°C), *maclura* (21.6°C), *Arecaceae* (20.7°C), *Pariteria / Urticaceae* (17.5°C), *Fagaceae* (16.4°C), *Umbelliferae* (19.1°C)
13. Low relative humidity or decreasing humidity, as compared to the previous day, enhanced pollen grain release to the atmosphere in 9 out of the 21 plant species: *Urticaceae* (64%), *Brassicaceae* (58%), *Eucalyptus* (60%), *Pistacia* (63%), *Poaceae* (60%), *Artemisia* (55%), *Pariteria/Urticaceae* (66%), *Fagaceae* (65%), *Umbelliferae* (67%).

**Figure 5:** Regression between spore concentration of *Alternaria* and temperature at the main and the **PP**.




14. A high temperature and a rise of the temperature, as compared to the previous day, with low relative humidity and a decrease trend from the previous days, were the most dominant weather factors in enhancing pollen in **SD**, but less than in the **PP** or in the main flowering season. Combining these two factors resulted in the airborne release of 3 pollen plants: *Parietaria/ Urticaceae, Brassicaceae* and *Umbelliferae.*
15. A combination of low temperature and low solar radiation with high relative humidity and a high barometric pressure enhanced the release of *Pinaceae* and *Phillyrea.*

## CONCLUSIONS

The presence of pollen and spores in the air was correlated especially with 3 meteorological variables (Tables 1-2 and Figures 3-5). High count of airborne pollen and spores highly and positively correlated with air temperature in all three studied periods, excluding the **SD** of spores. Temperature values measured on the previous day, in which there were high values of pollen grains of a number of plants and spores in the air, caused an increase of the concentration of pollen and spores. A decrease of the relative humidity or atmospheric pressure often results in an increase of airborne pollen and spore count in the main flowering period and in the **PP**. A decreased atmospheric pressure of the previous day influences a number of spores in the **PP**.

The effect of higher temperatures on allergens is apparent in this study. When temperatures were higher than those of the previous day or even due to the seasonal warming, most of pollen and spore concentrations increased. These results may be used to alert allergic patients during the flowering season and in the **SD**, when the temperature is supposed to rise, or when relative humidity or atmospheric pressure are supposed to decrease.

As most scenarios for climate change forecast a temperature increase in our region (the differences among the various models are only in the rate and timing of temperature rise), the present results imply intensification and elongation of the **PP** which may enhance the periods when allergenic pollen or spores will be released to the air.

## ACKNOWLEDGEMENTS

The authors thank the Haifa Bay Municipal Association for the Protection of the Environment, which allowed the installation of the Burkard volumetric pollen trap at their station, and provided the climatic data. In addition, thanks are due to Mrs. V. Epstein from the Allergenic Pollen Alert at Tel Aviv University, who helped in the identification of pollen grains and spores.

## REFERENCES

Corden, J. M., Millington, W. M., and Mullins, J. (2003) Long-term trends and regional variation in the aeroallergen Alternaria in Cardiff and Derby UK: Are differences in climate and cereal production having an effect? *Aerobiologia,* 19: 191-199

Galán C., Tormo, R., Cuevas, J., Infante, F. and Domínguez, E. (1991) Theoretical daily variation patterns of airborne pollen in the South-west of Spain. *Grana,* 30: 201-209

Gioulekas, D., Balafoutis, C., Damialis, A., Papakosta, D., Gioulekas, G. and Patakas, D. (2004) Fifteen years' records of airborne allergenic pollen and meteorological parameters in Thessaloniki, Greece. *International Journal of Biometeorology,* 48: 128-136.

Green, B, J., Yli-Panula, E., Dettmann, M., Rutherford, S. and Simpson., R. (2003) Airborne Pinus pollen in the atmosphere of Brisbane, Australia and relationships with meteorological parameters. *Aerobiologia,* 19: 47-55.

Hart, M. A., de Dear, R. and Beggs, P. J. (2006) A synoptic climatology of pollen concentrations during the six warmest month in Sydney, Australia. *International Journal of Biometeorology,* 51: 209-220.

Keinan, N. (1986) Pollen and spores as etiological factors of Hay Fever in Israel, Tel Aviv University (Unpublished ms., Hebrew)

Rantio-Lehtimaki, A. (1991) Sampling airborne pollen and pollen antigens. In D'Amato, G., Spieksma, F. Th. and Bonini, S. (eds.) *Allerenic Pollen and Pollinosis in Europe.* Blackwell Scientific: Melbourne, Paris, Berlin, Vienna, pp.18-23.

Riberio, H., Cunha, M., and Abreu, I. (2003) Airborne pollen concentration in the region of Braga, Portugal, and its relationship with meteorological parameters. *Aerobiologia,* 19: 21-27

Rodriguez-Rajo, F.J., Jato, V. and Aira, M.J. (2003) Pollen content in the atmosphere of Lugo (NW Spain) with reference to meteorological factors (1999-2001). *Aerobiologia,* 19: 213-225.

Stepalska, D., and Wolek, J. (2005) Variation in fungal spore concentrations of selected taxa associated to weather conditions in Cracow, Poland , in 1997. *Aerobiologia,* 21: 43-52.