

Pollen in aeolian dust with relation to allergy and asthma in Kuwait

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Abstract The studying of spatial and temporal distribution of pollen is essential, but rarely tackled in the region including Kuwait. Pollen grains and aeolian dust in the state of Kuwait were seasonally monitored from August 2009 to August 2011 to identify and correlate spatially and temporally pollen data with human health asthma and allergy data. The year 2010–2011 yielded a high in deposited dust and pollen compared to 2009–2010 by 33.2 and 9.9%, respectively. The spring (April–May) and the autumn (October–November) seasons marked the most top pollen distribution for Chenopodiaceae, Gramineae (Poaceae), Cyperaceae, Fabaceae, and Plantaginaceae. The pollen graphs for summer (July–August) and winter (January–February) seasons showed low pollen distribution due to the severe drought, dust storms, winter wind and rainfall. There are no correlations found between pollen deposition and the number of asthma patients. The annual dust deposited rate in Kuwait during 2010/2011 was 373 t km^{-2} which represented a 33.2% increase compared with

2009/2010. The study has concluded that pollen of Malvaceae, Compositae and Chenopodiaceae is the most common triggers of allergy in Kuwait. Additionally, a positive correlation between the number of allergy patients and deposited dust was observed during March 2010 and 2011.

Keywords Pollen · Aeolian · Dust · Flora · Allergy · Asthma · Kuwait

1 Introduction

The aeolian dust plays an integral role in most of the earth ecosystems (McTainsh and Strong 2007; Middleton and Kang 2017). A shared connection between pollen and aeolian dust was pointed out in Kenya (Mahaney et al. 1988), southeast Atlantic (Rommerskirchen et al. 2003), east China (Zhuo et al. 2007) and Australia (McTainsh and Strong 2007). “These transcontinental and transoceanic dust events inject a large pulse of pollen and microorganisms into the atmosphere and could, therefore, have a role in transporting pathogens or expanding the biogeographical range of some organisms by facilitating long-distance dispersal events” (Kellogg and Griffin 2006). It is essential to study the pollen content within aeolian deposition because of the possible health effects of pathogens and allergens that might be carried with these deposits (Kellogg and Griffin 2006).

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The airborne pollen and the seasonal distribution of the pollen grains in the atmosphere of Kuwait were studied by many researchers (Wilkinson 1964; Davies 1969; Halwagy and Halwagy 1984; Halwagy 1988, 1994; Al-Dousari et al. 2016). Wilkinson (1964) studied airborne pollen by gravity test slide method at the city of Ahmadi south of Kuwait City during early 1960(s) and he noted that *Prosopis* pollen is the main cause of allergy. Davies (1969) used a Hirst volumetric spore trap between August 1962 and March 1963 in the same city; he collected pollen grains on glass slides exposed for 24 h once every 2–3 days. Al-Awadhi (1973) contested that *Cynodon dactylon* (Gramineae) and *Chenopodium* were the primary sources of pollen contributors during early 1970(s) in Kuwait City.

Halwagy and Halwagy (1984) and Halwagy (1988) reported a preliminary survey of the seasonal distribution of airborne pollen grains at Kuwait city and Mena Al-Ahmadi. Daily observations were made using Hirst volumetric spore traps over 2 years (1975–1977) period whereby pollen as estimated at 2 h intervals. They observed two high and two low cycles of atmospheric pollen content. Mohamed et al. (1983) showed a highly significant correlation for allergy with the concentration of *Cyperus*, *Plantago* and *Brassicaceae* pollen, a substantial relationship with *Poaceae* and low association with *Prosopis*. Latif et al. (1989) reported that out of 100 patients, 70 showed a positive reaction to *Prosopis*, 69 to *Cynodon*, and 66 to *Chenopodium album* while 30 proved non-allergic to pollen.

Halwagy (1988) studied airborne pollen using Hirst volumetric spore traps simultaneously at three sites in Kuwait over a period of 5 years (1977–1982). Among the places, the highest counts were recorded at Ahmadi, followed by Kuwait city, while the lowest numbers were reported at Rawdhatain. Halwagy (1994) studied the amount of airborne pollen in Kuwait over a twelve-year period (1975–1987). Pollen occurs throughout the year, but the concentration of the various pollen types varied from year to year and from season to season. The highest counts were determined in 1978 and the lowest in 1986 (Halwagy 1994).

Dust is a common phenomenon in Kuwait, where the average annual total of dusty days is 255.4 days (Safar 1990). There are only a limited number of studies on the distribution of pollen grains associated

with aeolian sediments in the regions including Kuwait (<https://www.zaum-online.de/pollen-map>). All previous research in the regional area and Kuwait were case studies within urban areas. Therefore, the present study investigated pollen and aeolian dust over a wide range of desert and urban areas of Kuwait as a state from August 2009 to August 2011. The objectives of this study are to (1) identify and compare spatially and temporally fluctuation of pollen types and (2) study correlation between pollen obtained from aeolian samples and human health asthma and pollen allergy data.

2 Materials and methods

2.1 The study area

The climate of Kuwait is characterized by hot dry summers and cools to mild rainy winters. The rainfall pattern is typical for arid climates, being erratic with significant temporal and spatial fluctuations (Al-Dousari et al. 2008; Ahmed and Al-Dousari 2013). The average seasonal rainfall (October to April) total is 115 mm, fluctuating between 29 and 262.7 mm. Rainfall usually occurs between November and May, while occasional showers may fall during May (Al-Dousari et al. 2016). The mean temperature reaches its maximum during July–August (about 44 °C) and its minimum during January (about 8 °C). Mean values of relative humidity range between 90% in January and 31% in June, while the mean number of dusty days is 23 days during July and 9 days during December (Safar 1980). The northwesterly winds are the main driving force for the movement of dust and pollen grains in Kuwait and represent almost 60% of the total wind directions (Al-Dousari et al. 2016) (Fig. 1).

Open areas in Kuwait are typically highly degraded and mostly bare. Vegetation is restricted within farms, wadis and fenced or preserved areas. The drainage systems (wadis and basins) in northern Kuwait that extend all over petrogypsides soil type are topographically running from southwest toward northeast (Fig. 2a). Vegetation in Kuwait comprises eight units (mainly shrubs) described by (Omar 2000) as follows (Fig. 2b): HALOXYLETUM (Chenopodiaceae), RHANTERIETUM (Compositae), CYPERETUM (Cyperaceae), STIPAGROSTIETUM (Gramineae/Poaceae), ZYGOPHYLLETUM (Zygophyllaceae),

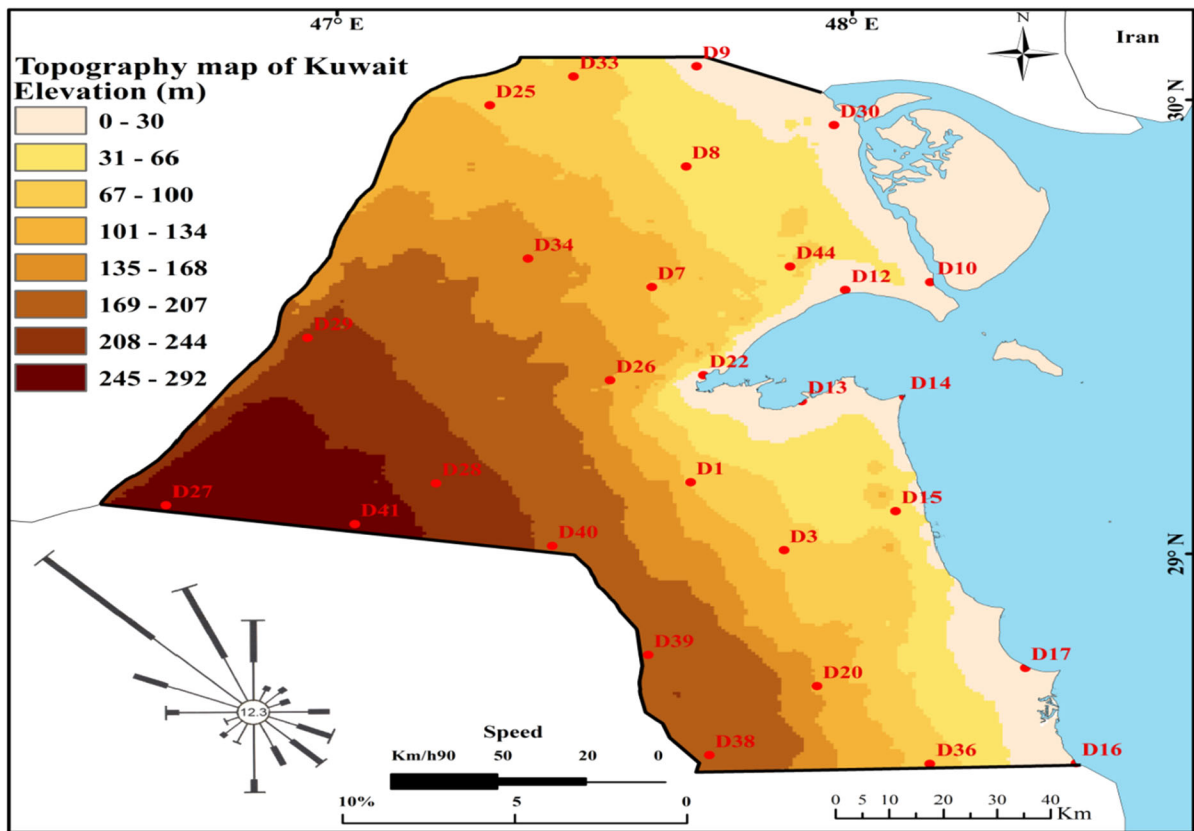


Fig. 1 Sampling sites with average wind rose 1962–1989 (Al-Kulaib 1990) on Kuwait topography map

CENTROPODIETUM (Gramineae/Poaceae), PANICETUM (Gramineae/Poaceae) and HALOPHYLETUM (Tamaricaceae).

2.2 Data and samples collection and preparation

Rainfall, humidity, asthma and pollen allergy patient data in the current study were collected from meteorological stations and Kuwait hospitals records and statistically analyzed.

A pair of pollen and dust traps was used per site on 28 sites covering the State of Kuwait (Fig. 3).

The study targeted pollen collected within aeolian samples in Kuwait; therefore, an adapted trap was used following the design by Al-Dousari and Al-Awadhi (2012) modified from dust trap designed by Reheis (1995) and Al-Awadhi (2005). The trap consists of a simple cylindrical container with 40 cm depth and 20 cm inner radius fixed at 0 cm for pollen and 240 cm for dust from ground level and designed to capture pouncing and suspended particles from all

directions. The sampling site locations were chosen to cover all geomorphological sectors and native vegetation areas in Kuwait. The samples within both traps were collected on a monthly basis for a 23-month period. The deposited dust rate unit was calculated based on the total weight of the deposited dust divided by area of the circle in dust trap and transferred into tons per square kilometer ($t\ km^{-2}$) as a shared unit used by numerous researchers (Pye 1992; McTainsh et al. 1997; O'Hara et al. 2006; Hoffmann et al. 2008). The collected samples from all pollen traps were weighted, mixed, quarterly split for homogeneity after that 50 g of each sample were sieved to $150\ \mu$. Ten grams of the sieved soil ($\leq 150\ \mu$) were washed with distilled water to remove the unwanted organic material and then subsequently dried. The dried fine dust was soaked in diluted HCL (10%), 40–60% HF and concentrated HCL to remove carbonates, silicates and fluorides existent in samples (Traverse 2007). The slide was then examined for pollen counts and identified to family, genus or other taxa. To obtain

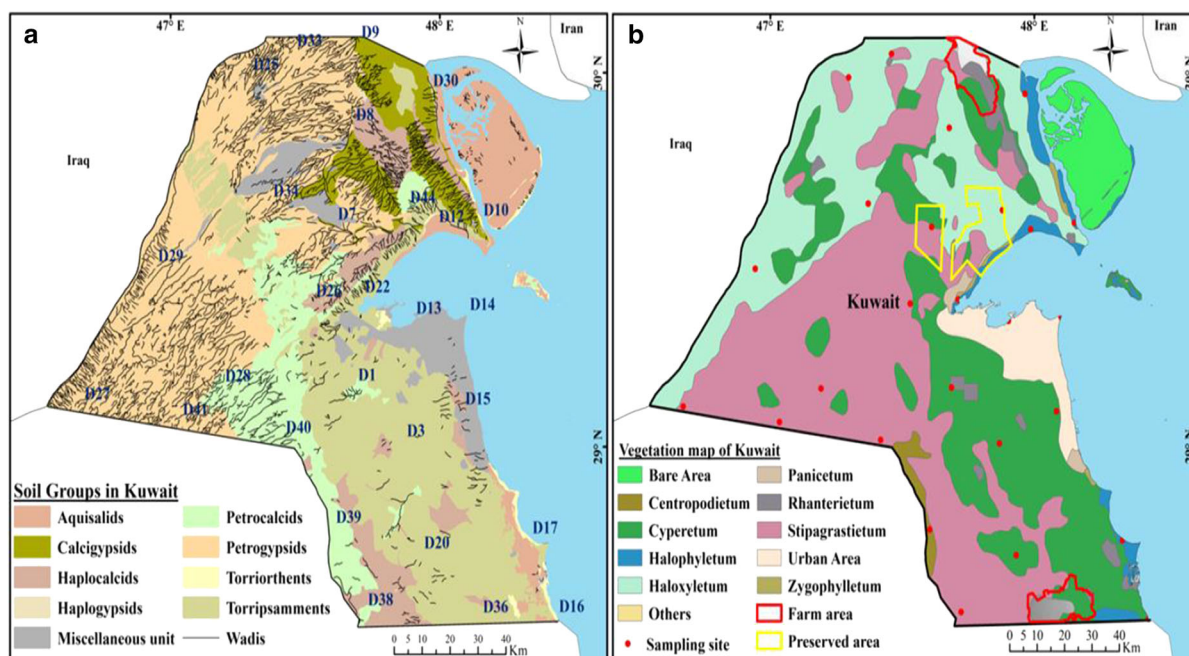


Fig. 2 Sampling sites, wadis, preserved areas and farms overlaying soil (a) and vegetation (b) maps of Kuwait (Omar 2000)



Fig. 3 Dust trap fixed at 240 cm above ground level (left) and pollen traps before and after fixing (right)

the classic pollen count, all pollen grains were obtained from 10 g for each sample, counted and identified over 2 years with two seasonal average pollen counts for fall, summer, spring and winter. Spearman's rho correlation is conducted to determine whether there is a monotonic association between allergy/asthma patients and pollen types.

2.3 Microscopic identification

The pollen grains or spores were visually identified and counted using high-power transmitted and fluorescent microscopes in reference to regional pollen collections at the Kuwait Institute for Scientific Research (KISR). Subsequently, a pollen diagram and graphical expression of pollen analysis were

constructed. A seasonal pollen diagram and a map showing pollen distributions in Kuwait were prepared for the following periods: (a) Fall (October–November 2009 and 2010), (b) Winter (January–February 2010 and 2011), (c) Spring (April–May 2010 and 2011) and (d) Summer (July–August 2010 and 2011). Each pollen data were stored as GIS layers using the ArcGIS S/W software, and geostatistical interpolator (Simple IDW method) was conducted to produce the pollen contour maps.

3 Results and discussion

During the 2010/2011 monitoring season, the amount of annual dust deposited in Kuwait amounted to 373 t km^{-2} which was 33.2% higher than in 2009/2010 (249 t km^{-2}) (Fig. 4). The areas with denser vegetation showed lower sampled dust (Fig. 5). This can be attributed to the capability of native vegetation in preserved areas to prevent the removal of dust particles after the first deposition. Significant increases in the number of pollen allergy patients in Kuwait hospitals records (2006–2012) were noted during October–December, January and March–

May (Fig. 6). The match between seasonal averages for a sum of pollen allergy patients and deposited dust was only observed during March 2010 and 2011. High significant Spearman's rho correlation coefficient (r_s) at the $p \leq .01$ was noted between allergy and both asthma and humidity ($r_s = 0.797$ and $r_s = 0.538$, respectively). As expected, a highly significant correlation between rainfall and humidity ($r_s = 0.630$, $p \leq .01$) were recorded. Significant correlations are detected at the $p \leq .05$ between both allergy and rainfall, and asthma and humidity; $r_s = 0.439$ and $r_s = 0.463$, respectively. There is no matching correlation was observed between dust fallout rates in relation to a sum of asthma patients, rainfall and humidity.

The microscopic investigation led to the identification of 21 pollen families and or groups (Table 1), eight of these are the most dominant, while others are found in traces or low percentages. Pinaceae pollen (2–3%) is a good example for pollen with low percentages and was detected at northern and north-western borders of Kuwait at site locations D9, 25, 27, 29 and 30.

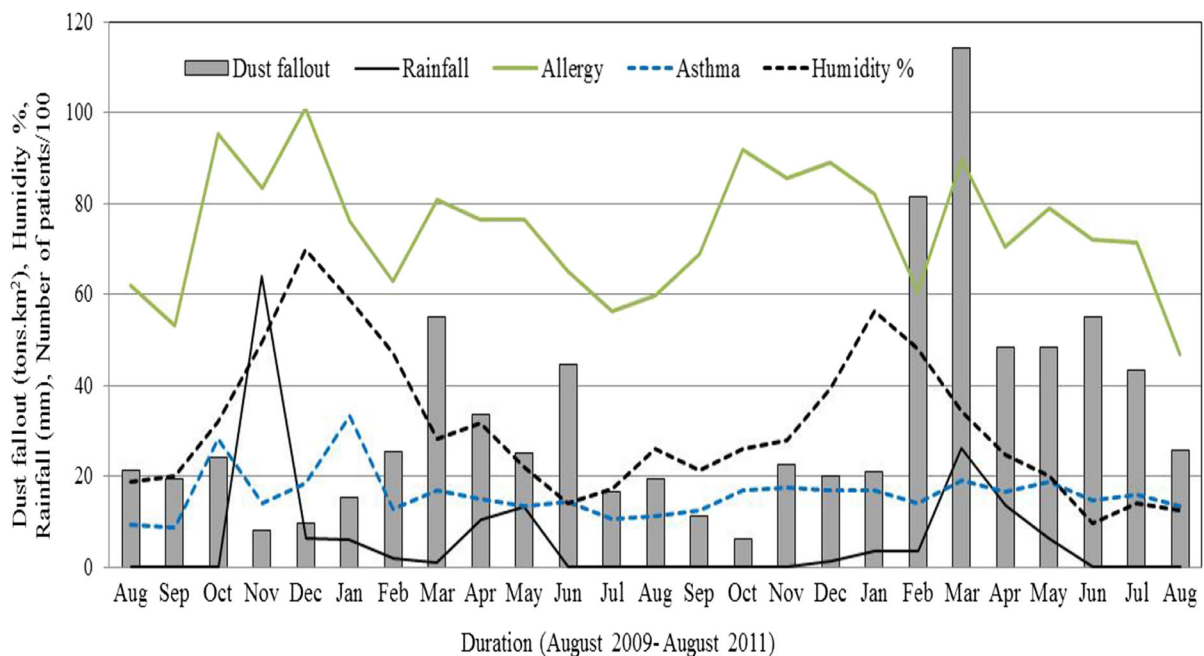


Fig. 4 Mean monthly deposited dust in Kuwait in relation to rainfall, humidity, and counts of allergy and asthma patients (divided by 100) in Kuwait

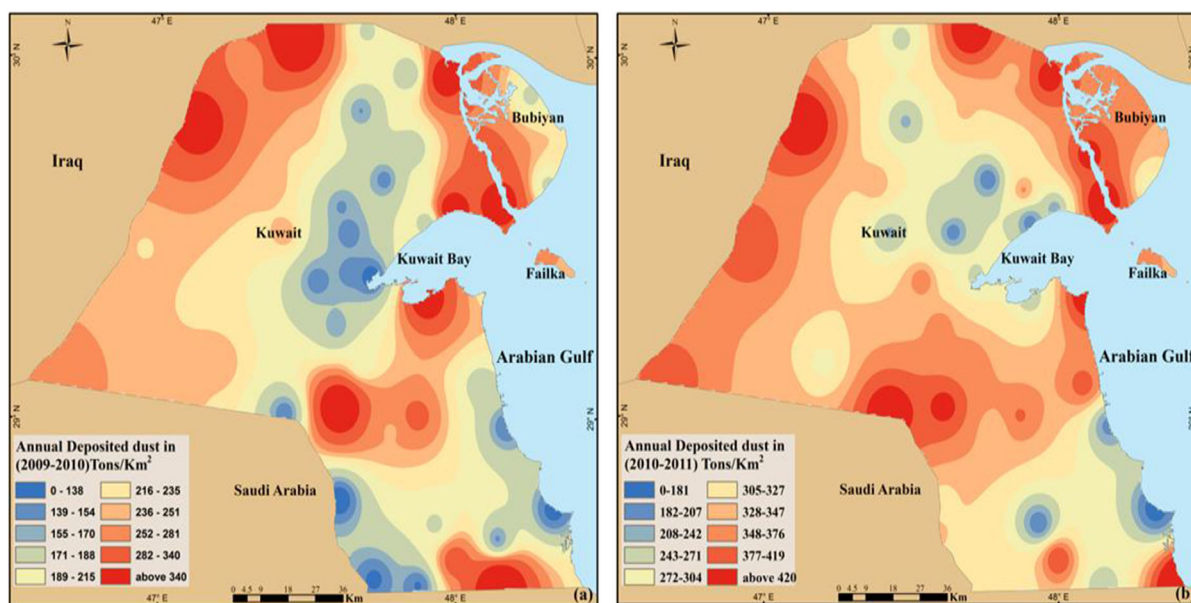


Fig. 5 Kuwait annual deposited dust in 2009–2010 (a) and 2010–2011 (b)

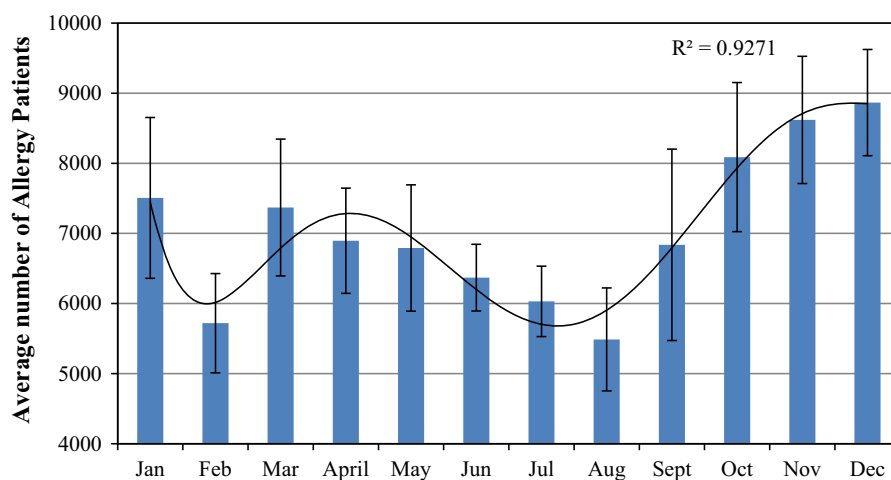


Fig. 6 Mean monthly counts and standard deviation of pollen allergy patients in Kuwait (2006–2012)

3.1 Seasonal variation

Pollen was remarkably different distinction between the year 2009–2010 and 2010–2011. The pollen counts of the period 2010–2011 are higher than that of the period 2009–2010 by 9.87%. It is also evident that pollen counts vary from season to season. Pollen counts over the four seasons for the 2 years (October 2009–August 2011) reveal the presence of two peaks in spring (April–May) and autumn (October–November). The first peak is higher and is due mainly to

pollen grain species which flower during the spring season such as Chenopodiaceae, Gramineae (Poaceae), Cyperaceae, Fabaceae (Leguminosae), and Plantaginaceae. The second peak in autumn is lower and is characterized by the abundance of Chenopodiaceae and Fabaceae.

On the other hand, two troughs (low pollen content) have been observed during summer (July–August) and winter (January–February) seasons due to summer drought, dust storm and winter wind and rainfall. The summer lows are characterized by higher counts than

Table 1 Summary counts and percentages for 21 pollen/spore families in Kuwait

Pollen taxa	First year		Second year	
	Counts	%	Counts	%
Chenopodiaceae	3310	31.0	3680	31.4
Fabaceae	1857	17.4	1624	13.8
Gramineae/Poaceae	1527	14.3	1855	15.8
Cyperaceae	2395	22.4	2852	24.3
Plantaginaceae	515	4.8	472	4.0
Brassicaceae	147	1.4	175	1.5
Malvaceae	331	3.1	308	2.6
Compositae	137	1.3	163	1.4
Zygophyllaceae	43	0.4	46	0.4
Euphorbiaceae	5	0.0	57	0.5
Pinaceae	119	1.1	203	1.7
Trilete spore	44	0.4	40	0.3
Liliaceae	19	0.2	23	0.2
Ephedraceae	132	1.2	140	1.2
Convolvulaceae	21	0.2	16	0.1
Juncaceae	16	0.1	13	0.1
Acanthaceae	6	0.1	7	0.1
Plumbaginaceae	25	0.2	29	0.2
Geraniaceae	10	0.1	11	0.1
Tamaricaceae	12	0.1	11	0.1
Cicatricose spore	2	0.0	2	0.0
SUM	10,673	100	11,727	100

the winter lows. This is convenient with previous studies in Kuwait (Davies 1969; Halwagy and Halwagy 1984; Behbehani et al. 2003; Sabbah et al. 2014). The pattern of the pollen counts is persistent and shows a consistent annual cycle (Sabbah et al. 2014).

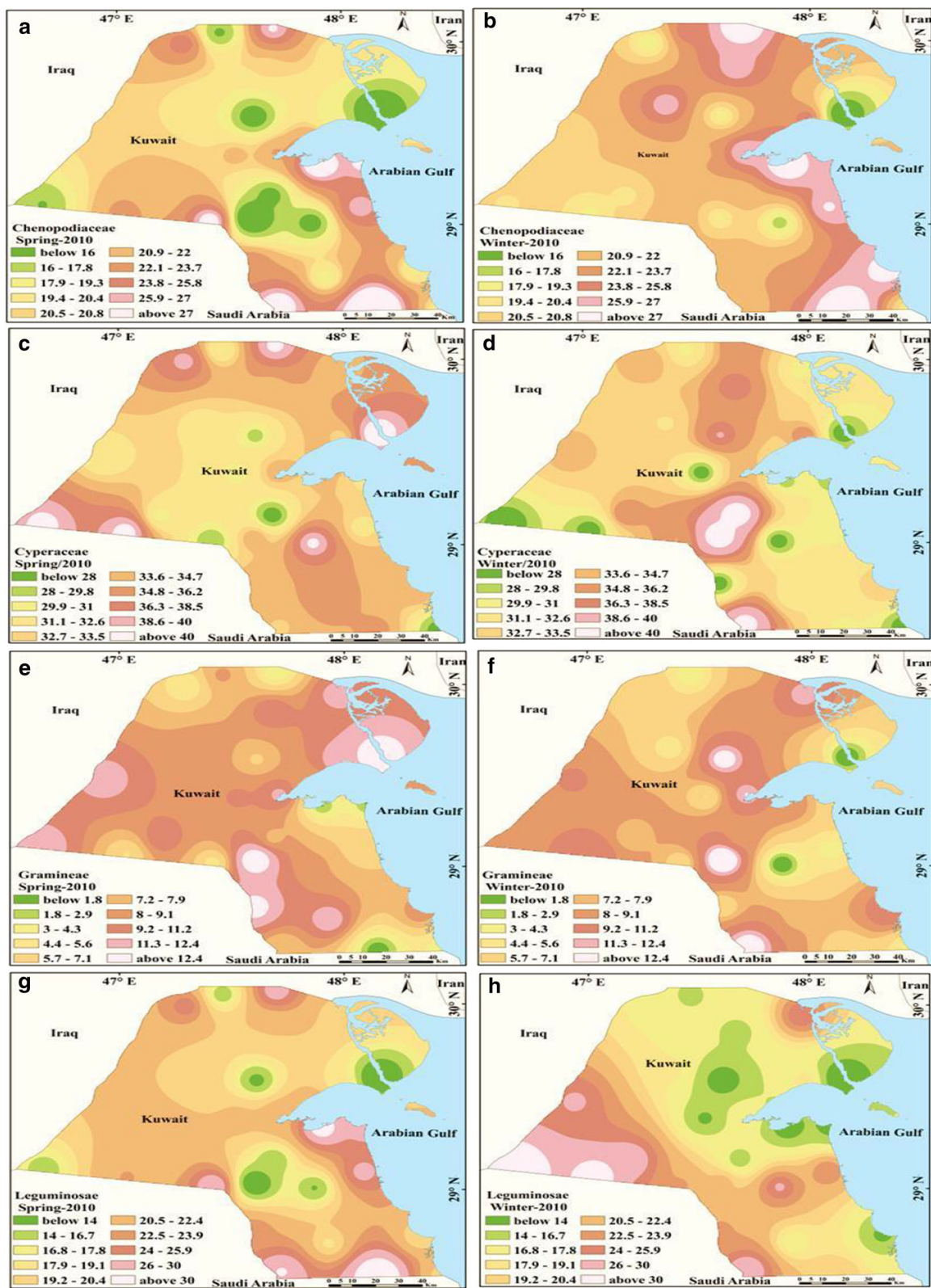
Among the 28 sites, the highest counts over the 2 years of study were recorded at sites D8, 10, 22 and 12 in descending order, especially in autumn and spring seasons. The highest pollen counts at later mentioned sites can be attributed to the geographical location of the dust traps as they all located in northern Kuwait which is characterized by the denser drainage system (wadis) compared to other areas, the location within dust storms major trajectories (Fig. 7) and the petrogypsides soil type (Fig. 2a) and flora biodiversity (Fig. 2b).

In autumn 2010, the highest pollen counts were due to Chenopodiaceae (57%) followed by Fabaceae (22%), Plantaginaceae (7%), Malvaceae (7%) and Gramineae (6.5%). The highest pollen counts were recorded at sites 13, 15, 14 and 7 in descending order. In autumn 2010, pollen types and counts show nearly the same trend as in 2011, where Chenopodiaceae pollen dominates the counts (45%) followed by Fabaceae (16%), Gramineae (8%), Plantaginaceae (5.7%) and Cyperaceae (5.6%). The highest pollen counts were recorded at sites 13, 14, 15, 7 and 20 in descending order.

In winter 2010, Chenopodiaceae dominates the counts (52%) followed by Fabaceae (12.2%), Gramineae (7.6%), Pinaceae (exotic transported bisaccate pollen, 5.7%), Plantaginaceae (5.2%), Malvaceae (4.4%) and Cyperaceae (4%). In winter 2011, the highest pollen counts were due to Chenopodiaceae (43%) followed by Fabaceae (18.8%), Gramineae (10%), Pinaceae (6.4%), Cyperaceae (6.2%) and Plantaginaceae (4.6%). The highest counts were recorded at sites 13, 14, 15, 7 and 20 in descending order.

In spring 2010, the abundant pollen families belonged to Cyperaceae (33.6%) followed by Chenopodiaceae (24%), Gramineae (19.6%), Fabaceae (11.7%), Plantaginaceae (4.4%), Malvaceae (2.1%) and Ephedraceae (1.2%). The sites which show highest counts are 13, 15, 14, 9, 33, 7 and 30 in descending order. In spring 2011, pollen distribution and abundance show similar trend to spring 2010 with the abundance of Cyperaceae (33.7%) followed by Chenopodiaceae (24.9%), Gramineae (19.3%), Fabaceae (12%), Plantaginaceae (3.2%), Malvaceae (1.9%), Ephedraceae (1.2%) and Brassicaceae (1.1%). The sites which show highest counts are 13, 15, 14, 33, 9, 29 and 20 in descending order.

In summer 2010, the highest counts were due to Chenopodiaceae (32.8%) followed by Fabaceae (23.2%), Cyperaceae (18.7%), Gramineae (11.5%), Plantaginaceae (4.3%), Malvaceae (2.3%) and Ephedraceae (2.1%). The same trend was observed in summer 2011 with nearly the same dominance percentage (Chenopodiaceae, 33%; Fabaceae, 24%; Cyperaceae, 19.4%; Gramineae, 18.9%; Plantaginaceae, 3.5%; Malvaceae, 1.8% and Ephedraceae, 1.6%). The highest count was observed at sites 7, 34, 20, 15, 8 and 1 in descending order.



distribution was recorded during autumn 2009 and 2010 (up to 54%) on the extreme western side of the country. The lowest pollen counts were recorded in the south of Kuwait Bay (autumn 2009), eastern side (winter 2010), and southern Kuwait (spring 2011 and summer 2011). The dominant genera in Kuwait are *Acacia*, *Astragalus*, *Coronilla*, *Lotus*, *Medicago*, *Prosopis*, *Scorpiurus* and *Trigonella*.

Gramineae pollen counts show a high peak during spring 2010 and 2011. The highest percentages (22–24%) were observed during spring 2010 and 2011 on the central and northern parts of Kuwait. Also, a high count percentage (18–24%) was observed during summer 2010 in the northwestern side of Kuwait. The lowest pollen count was recorded in the southern and southeastern parts of Kuwait during summer 2010 and 2011. The most common genera are *Aeluropus*, *Asthenatherum*, *Bromus*, *Cynodon*, *Dichanthium*, *Pennisetum*, *Panicum*, *Phragmites*, *Schismus* and *Stipagrostis*.

Cyperaceae showed a high peak during spring (2010, 2011) and summer (2011). The highest counts were recorded during spring and summer (2010, 2011) in the north; south and east (spring 2011). Generally, the lowest pollen counts were observed in autumn and

winter all over the country. Cyperaceae is represented by *Cyperus conglomerates* and *C. rotundus*.

3.3 Allergy and asthma in relation to pollen

The pollen in deposited dust is the most common triggers of allergy and asthma in Kuwait. Chenopodiaceae in particular were found highly correlated to counts of allergy patients in Kuwait. A correlation was also found between the number of allergy patients pass to the hospitals and clinics with Cyperaceae and Gramineae during spring time only. Although Compositae pollen was present in appreciable amounts, there was no effect noted on allergy number of patients. There are no correlations noted between pollen and number of asthma patients (Fig. 9). The Spearman's rho correlation matrix (Table 2) shows that there is a significant positive relationship between allergy patients and both Malvaceae pollen ($r_s = 0.756$, $p = 0.03$), Compositae pollen ($r_s = 0.835$, $p = 0.01$) and Chenopodiaceae ($r_s = 0.60$, $p = 0.12$). In other words, we can conclude that the strength of association between allergy patients and Malvaceae pollen is significant with 95% confidence and that the strength of association between allergy patients and Compositae pollen is significant with 99% confidence.

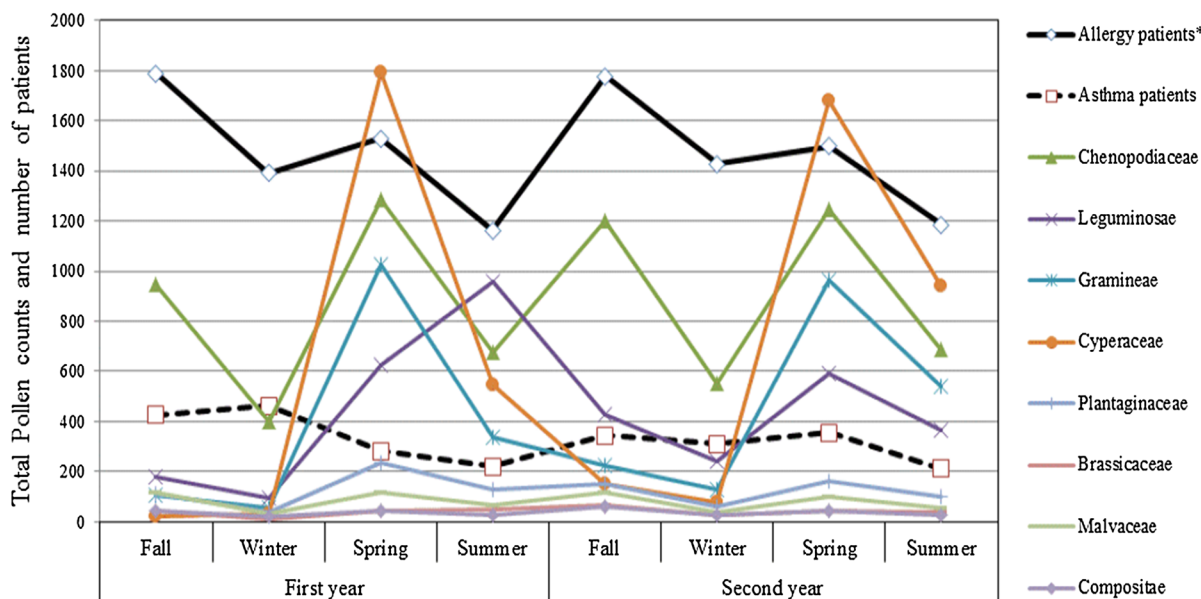


Fig. 9 Major pollen family counts for two seasons concerning the number of allergy and asthma patients (Allergy patient's numbers were divided by 10 to fit in the graph) in Kuwait

Table 2 Spearman's rank correlation for pollen types, allergy and asthma patients in Kuwait

No.	Items	1	2	3	4	5	6	7	8	9	10
1	Allergy patients	1.00									
2	Asthma patients	0.50	1.00								
3	Chenopodiaceae	0.60	− 0.12	1.00							
4	Fabaceae	− 0.19	− 0.62	0.55	1.00						
5	Gramineae	− 0.07	− 0.62	0.74*	0.81*	1.00					
6	Cyperaceae	− 0.19	− 0.60	0.64	0.79*	0.98**	1.00				
7	Plantaginaceae	0.41	− 0.21	0.93**	0.79*	0.79*	0.71*	1.00			
8	Brassicaceae	0.26	− 0.19	0.59	0.71	0.41	0.32	0.74*	1.00		
9	Malvaceae	0.76*	0.00	0.85**	0.42	0.39	0.24	0.81*	0.71*	1.00	
10	Compositae	0.84**	0.09	0.84**	0.23	0.36	0.23	0.70	0.61	0.87**	1.00

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

Significant more than/equal 0.6

4 Conclusions

There was a significant positive relationship between allergy patients and both Malvaceae pollen, Compositae pollen and Chenopodiaceae. It is concluded that the Malvaceae, Compositae and Chenopodiaceae pollen are the most common triggers of allergy in Kuwait. The later conclusion is convenient with other local (Behbehani et al. 2000, 2004; Sabbah et al. 2014) and regional studies at downwind in Saudi Arabia (Hasnain et al. 2005) and upwind in Iraq (Al-Dabbas et al. 2012).

The continuously monitored pollen and deposited dust in the state of Kuwait from August 2009 to August 2011 led us to conclude that traps in and surrounding drainage systems show high pollen counts. Low percentages (1–2%) of Pinaceae pollen were recorded in the north and northwest borders of Kuwait with Iraq (D9, 25, 27, 29 and 30) which could be interpreted as being transported by the northwesterly wind from long-distance regional sources. The closest pine trees in the regional scale are in northern Iraq and Syria, Lebanon and Turkey. It is also concluded that areas that experience low depositional dust are showing a greater count of pollen. The years 2010–2011 experienced a high pollen count and deposited dust compared to 2009–2010 which indicates the decrease in native vegetation in the region which causes the increase in deposited dust rates. The pollen counts can be taken as an indicator for vegetation density deterioration rate. The pollen distribution reached its maximum peak at the end and the start of the rain season in spring (April–May)

and autumn (October–November) seasons, which indicates that the pollen counts highly related to climatic conditions and distribution of drainage system (wadis). The spring season marked the highest pollen distribution due to the flowering of a more significant number of *Chenopodiaceae*, *Gramineae* (*Poaceae*), *Cyperaceae*, *Fabaceae* and *Plantaginaceae*. The summer (July–August) and winter (January–February) seasons recorded low counts for the pollen distribution due to the severe drought, dust storms, winter wind and rainfall. The winter season represented the lowest pollen count.

Further studies should be focused on adaptation with dust storm by proper sustainable controlling measures.

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