ACTA AGROBOTANICA
Vol. 62 (1): 3–8
2009

THE SPORES OF *Alternaria* IN AEROPLANKTON AND ITS RELATIONSHIPS WITH THE METEOROLOGICAL FACTORS

Agnieszka Grinn-Gofroń

Department of Plant Taxonomy and Phytogeography, Faculty of Natural Science
University of Szczecin, Wąska 13, 71-415 Szczecin, Poland
e-mail: agofr@univ.szczecin.pl

Received: 16.02.2009

Abstract

Alternaria spores are known to be potent aeroallergens and their concentrations in the air are strongly dependent on meteorological factors. There are many articles from different parts of the world about relationships between *Alternaria* spore count and weather parameters. The aim of the study was to review all available publications about airborne *Alternaria* spores and compare the results in short, useful form.

Key words: *Alternaria*, airborne spores, meteorological factors, statistical correlation

INTRODUCTION

The form-division Fungi Imperfecti or Deuteromycota is an artificial category. Members of this group were originally combined into a single group because they apparently lacked a sexual stage. Fungi Imperfecti are divided into form-classes based upon morphological similarities. The criteria that are typically used are colour, shape, size and septation of the conidia (whether the spores are unicellular, or made up of multiple cells). Many of the spores of the Fungi Imperfecti have morphologically distinct features so that the spores from this group are some of the most easily identified. Many are also easily cultured so that more research has been conducted upon this group of fungi than many other. *Alternaria*, *Cladosporium*, *Curvularia*, *Drechslera*, *Epicoccum*, *Fusarium*, *Nigrospora* and *Stemphylium* were listed by Kendrick (1990) as the 'Big Eight' because of their allergenicity and frequency in the air.

The knowledge of the composition of airborne spores of a particular area is important in agriculture, because crop pathogens can be identified to prevent crop epidemics and also because some of them act as factors for causing respiratory allergy to susceptible individuals. The characteristic features and size of the spores determine how deep they may penetrate into the respiratory tract, whereby the exact site of allergic response can be determined. Spores larger than 10 µm in diameter are deposited in the nasopharynx causing rhinitis; spores smaller than 5 µm penetrate to the alevoli causing alevolitis. Spores <10 µm in size mostly deposit in the bronchi and bronchioles causing asthma (Lacey et al. 1972).

One of the most important genus belonging to that group is *Alternaria*. There is a number of very similar, related species which are usually grouped together as *Alternaria*. The spores are multi-celled. The conidiophores are dark, simple, rather short or elongate, typically bearing a simple or branched chain of conidia. The conidia are also dark, multi-septate, both transverse and longitudinal. They vary in width and length according to species, usually 8 to 75 micrometers in length; some species, such as *Alternaria longissima*, can be found with a length of up to 500 micrometers (0.5 milimeters).

Alternaria, which is both ubiquitous and abundant, is both saprophytic and parasitic on plant material and is found on rotting vegetation as well as in damp indoor areas, such as bathrooms. The spores are present in large number throughout the late summer, especially at the harvest time (Hyde and Williams, 1946). Geographically, the fungus is distributed worldwide but is particularly prevalent in dry climates.

Certain fungal spores are known to cause an allergic response and spores of the genus *Alternaria* have been known to trigger asthma for over 50 years (Hopkins et al. 1939). The risk of asthma-related deaths is more than doubled when there is a high incidence of mould spores (Targonsky et al. 1995) and *Alternaria* is a known risk factor in childhood and young adult asthma (O'Hollaren et al. 1991; Tariq et al. 1996; Dutkiewicz, 1997).

Alternaria spores vary in size, but L i c o r i s h et al. (1985) said it could be safely assumed that even the larger *Alternaria* spores could penetrate the lungs causing asthma. If more *Alternaria* spores are being released into the air, even though only a small percentage of the population is involved, then a considerable number of patients may have severe asthma attacks during the *Alternaria* season.

Literature has a few references to the number of spores that are needed to provoke an allergic reaction in susceptible individuals. One estimated threshold concentration of *Alternaria* spores needed to provoke an allergic response is 100 spores × m^{-3} of air (G r a v e s e n , 1979). L i c o r i s h et al. (1985), however, suggests that the order of 10^4-10^7 spores is needed to be inhaled over 24-h period. H a s n a i n (1993) suggests that mean daily concentrations of 50 *Alternaria* spores/m^3 are needed to cause sensitization, after which smaller concentrations can cause symtoms. In Poland R a p i e j k o et al. (2004) reported that a subject with hypersensitivity to *Alternaria* allergens experienced the symptoms during exposure to a concentration of approximately 80 spores × m^{-3} of air.

The highest concentrations

The monitoring of fungal spores in Poland revealed the summer as the most favourable season for *Alternaria* occurrence (G a w e ł , 1996; S t ę p a l s k a et al. 1999; K a s p r z y k et al. 2004; K o n o p i ń s k a , 2004; S t ę p a l s k a and W o ł e k , 2005; G r i n n - G o f r o ń and S t r z e l c z a k , 2008). Also in Denmark (L a r s e n and G r a v e s e n , 1991) and Sweden (H j e l m r o o s , 1993), the highest number of *Alternaria* spores was usually encountered during summer. In Cordoba (I n f a n t e and D o m i n q u e z , 1988) and on Sardinia (C o s e n t i n o et al. 1990), a decrease in the *Alternaria* spore concentration was observed in summer. The summer decrease is related to high temperature and lack of rain. Maximum concentrations were found in Cordoba to occur in both late spring and autumn (A n g u l o - R o m e r o et al. 1999). Contrary to these results in Amman (Jordan), maximum *Alternaria* spore counts were recorded in October, because of wet, warm, conditions (S h a h e e n , 1992). In the United States, various surveys have reported *Alternaria* more frequently than other moulds (except on the Pacific Coast where this taxon was found only sporadically or in reduced numbers (D ' A m a t o and S p i e k s m a , 1995).

Correlations with meteorological factors

Maximum temperature

A positive and statistically significant correlation between the daily *Alternaria* spore concentration and the maximum temperatures has been found in Szczecin (G r i n n - G o f r o ń , 2008) and has been reported from other sites in Poland (S t ę p a l s k a and W o ł e k , 2005), United States (L e v e t i n and D o r s e y , 2006), United Kingdom (C o r d e n and M i l l i n g t o n , 2001) and Spain (F e r n á n d e z et al. 1998). H e r r e r o et al. (1996) studied the relationship between daily concentrations of *Alternaria* and meteorological variables. They found *Alternaria* to be positively correlated with maximum temperature.

Minimum temperature

The correlation between *Alternaria* spore count and minimum temperature was not significant in all available publications.

Mean temperature

The content of *Alternaria* spores in the atmosphere increases when mean temperatures rise; these results are very similar to those obtained by other authors (I n f a n t e and D o m i n q u e z , 1988 (Cordoba, Spain); G o n z á l e s M i n e r o et al. 1994 (Spain); R i c c i et al. 1995; M é n d e z et al. 1997 (Spain), who considered that this factor played a major role in the dispersion of *Alternaria*. Positive, significant correlations with temperature, similar to those observed in Poland, have been reported extensively in other cities throughout the world by P a l m a s and C o s e n t i n o , 1990 (Sardinia, Italy); R o s a s et al. 1990 (Mexico); S r i v a s t a w a and W a d h w a n i , 1992 (SE Spain); (F e r n á n d e z - G o n z á l e s et al. 1993 (Leon, Spain); Hjelmroos, 1993 (Stockholm, Sweden); M i t a k a k i s et al. 1997 (Melbourne, Australia); P a r e d e s et al. 1997 (Mexico); M u n u e r a G i n e r et al. 2001 (SE Spain); T r o u t t and L e v e t i n , 2001 (Tulsa, United States); S a k i y a n and I n c e o ğ l u , 2003 (Ankara, Turkey).

Relative humidity

The *Alternaria* spores count was negatively and statistically significantly correlated with relative air humidity, however, a positive correlation (increased spore count in the air with increased relative humidity) was noted by S t ę p a l s k a and W o ł e k (2005) in Cracow, by H j e l m r o o s (1993) in Stockholm and in Ankara (S a k i y a n and I n c e o ğ l u , 2003). The concentration of *Alternaria* spores in the suburbs of Mexico City was found by C a l d e r o n et al. (1997) to be positively correlated with relative humidity on the previous day. G i n e r and G a r c i a (1995) in Murcia (Spain) found that daily concentrations of *Alternaria* spores were positively correlated with relative humidity but not significantly.

Rainfall

A significant and negative correlation between the *Alternaria* spores concentration and daily precipitation was noted by Stępalska and Wołek in Cracow (2005), Mitakakis et al. (1997) in Australia, Corden and Milington (2001) in the United Kingdom and Sakiyan and Inceoğlu, (2003) in Turkey. Herrero et al. (1996) reported a positive correlation with rainfall. Giner and Garcia (1995) found that daily concentrations of *Alternaria* spores were positively correlated with precipitation but not significantly. Gregory and Hirst, (1957) in Rothmasted found high *Alternaria* spore concentrations most often in August, in warm, dry spells after a period of wet weather. Based on the available publications, we have some evidence that although high daily *Alternaria* spore levels occur on dry days, occasional rainfall results in higher monthly concentrations of *Alternaria* spores than that in a longer dry period. In Amman the maximum *Alternaria* spore counts in the air were noted in warm, wet conditions (Shaheen, 1992).

Wind speed

In Szczecin, which is almost flat, wind speed was not significantly correlated with spore concentrations (Grinn-Gofroń, 2008). In Stockholm Hjelmroos (1993) noted that the concentration of *Alternaria* spores was favoured by relatively strong winds. Similar results occurred in Ankara (Sakiyan and Inceoğlu, 2003). A negative correlation between the *Alternaria* spores count and the wind speed was observed by Levetin and Dorsey (2006) in Tulsa (United States) and by Hasnain, (1993) in Auckland (New Zeland). Lopez and Salvaggio (1983) also confirmed that high wind speed produced a decreased atmospheric concentration of *Alternaria* spores count. Giner and Garcia (1995) found that daily concentrations of *Alternaria* spores were positively correlated with wind speed but not significantly.

Pressure

Hjelmroos (1993) noted a negative significant correlation for *Cladosporium* in Sweden and for *Alternaria* the correlation was not statistically significant. A highly significant negative correlation between air pressure and *Alternaria* spore concentration was found by Stennett and Beggs (2004) in Sydney, although this occurred only on the same day and with one day lag.

Dew point temperature

Troutt and Levetin (2001), in the results of multiple regression analysis which was performed using a forward stepwise mode, showed a significant negative correlation between *Alternaria* spore count and dew point temperature but positive for temperature. They conclude that temperature and dew point are probably the best predictors for *Alternaria*, appearing with positive and negative relationships in all regressions.

Statistical models

A better understanding of the relative importance of weather parameters and their interrelationships would help determine the role of spore dispersal in allergies to airborne fungal spores. However, there are comparatively few advanced forecasting models of airborne fungal spore circulation (Katial et al. 1997), and most of them usually display low predictability (Angulo-Romero et al. 1999; Mitakakis et al. 2001; Stennett and Beggs, 2004).

Herrero et al. (1996) noted a positive significant correlation for precipitation using two statistical analyses: multiple regression and Duncan's multiple range test. Lyon et al. (1884), using multiple regression analysis, also noted that the maximum and minimum temperatures are significantly correlated with concentrations of *Alternaria*. Damialis and Gioulekas (2006) used the autoregressive predictive models and observed *Alternaria* spores were strongly related to air temperature. The interaction effects of rainfall and wind were also considered necessary for long-term (annual) predictions of airborne fungal concentrations.

Spearman's rank correlation coefficient and also multiple regression were used by Stennett and Beggs (2004) in Sydney. The daily mean, minimum and maximum temperature and dew point temperature were most strongly and consistently associated with the concentration of *Alternaria* spores. The same authors found positive, but markedly lower and less consistent, relationships between *Alternaria* spore concentration and rainfall 2 and 3 days previously and relative humidity in the previous 1, 2 and 3 days.

Contrary to the results presented above, Hjelmroos, (1993) and Katial et al. (1997) noted no statistically significant correlation between *Alternaria* spore count and weather variables and they consider that no statistical model can be proposed for *Alternaria* spore concentrations in relation to climate.

The models created by Grinn-Gofroń and Strzelczak (2008) for relationships between *Alternaria* spore concentrations and meteorological factors are based mainly on the artificial neural network (ANN) method. All variables, except maximum wind speed and precipitation, were important factors in the overall classification model. In the regression model for spore seasons, close relationships were noted between

Alternaria spore concentration, average and maximum temperature (on the same day and 3 days previously), humidity (with lag 1) and maximum wind speed 2 days previously. The most important variable was humidity recorded on the same day.

That study shows the novel approach to modelling of time series with short spore seasons and indicates that the ANN method gives the possibility of forecasting *Alternaria* spore concentration with high accuracy.

CONCLUSIONS

- Maximum and mean temperature were positively and statistically significantly correlated with *Alternaria* spore concentration.
- The negative correlation was found for five weather parameters: rainfall, humidity, pressure, dew point temperature and wind speed.
- No authors found significant, statistical relationships with minimum temperature.
- From the present point of view, simple statistical methods are inadequate for defining which meteorological parameter has the strongest influence on *Alternaria* spore concentration in the air.
- The statistical, predictive models are functional and define more precisely the values of weather factors. This is useful for describing spore seasons and creating spore calendars for allergologists.

REFERENCES

Angulo-Romero J., Mediavilla-Molina A., Dominquez-Vilches E., 1999. Conidia of *Alternaria* in the atmosphere of the city of Cordoba, Spain in relation to meteorological parameters. Int. J. Biometeorol. 43: 45-49.

Calderon C., Lacey J., McCartney A., Rosas I., 1997. Influence of urban climate upon distribution of airborne *Deuteromycetes* spore concentrations in Mexico City. Int. J. Biometeorol. 40: 71-80.

Corden J. M., Millington W. M., 2001. The long-term trends and seasonal variation of the aeroallergen *Alternaria* in Derby, UK. Aerobiologia, 17: 127-136.

Cosentino S., Pisano P. L, Fadda M. F., Palmas F., 1990. Pollen and mould allergy: aerobiological survey in the atmosphere of Caligari, Italy (1986-1988). Ann. Allergy, 65: 393-399.

D'Amato G., Spieksma F. Th. M., 1995. Aerobiologic and clinical aspects of mould allergy in Europe. Allergy, 50: 870-877.

Damialis A., Gioulekas D., 2006. Airborne allergenic fungal spores and meteorological factors in Greece: Forecasting possibilities. Grana, 45: 122-129.

Dutkiewicz J., 1997. Bacteria and fungi in organic dust as potential health hazard. Ann. Agric. Environ. Med. 4: 11-16.

Fernández D., Valencia R. M., Molnar T., Vega A., Sagues E., 1998. Daily and seasonal variations of *Alternaria* and *Cladosporium* airborne spores in Leon (North-West, Spain). Aerobiologia, 14: 215-220.

Fernández-Gonzáles D., Suárez-Cervera M., Diaz-Gonzáles T., Valencia-Barrera R. M., 1993. Airborne pollen and spores of León (Spain). Int. J. Biometeorol. 37: 89-95.

Gaweł J., Halota A., Pisiewicz K., Kurzawa R., Radliński J., Doniec Z., 1996. Allergenic airborne sporomorphs calendar for Rabka (southern Poland), 1991-1995. Ann. Agric. Environ. Med. 3: 87-98.

Gonzáles Minero F. J., Candau P., Cepeda J. M., 1994. Presencia de esporas de *Alternaria* enel aire (SO de España) y su relación con factores meteorológicos. Revista Iberoamericana de Micología, 11: 92-95.

Gravesen S., 1979. Fungi as a Cause of Allergic Disease. Allergy, 34: 135-154.

Gregory P. H., Hirst J. M., 1957. The summer Air-Spora at Rothamsted in 1952. J. Gen. Microbiol. 17: 135-152.

Grinn-Gofroń A., 2008. The variation in spore concentrations of selected fungal taxa associated with weather conditions in Szczecin, Poland, 2004-2006. Grana, 47 (2): 139-146.

Grinn-Gofroń A., Strzelczak A., 2008. Artificial neural network models of relationships between *Alternaria* spores and meteorological factors in Szczecin (Poland). Int. J. Biometeorol. 52: 859-868.

Hasnain S. M., 1993. Influence of meteorological factors on the air spora. Grana, 32: 184-188.

Herrero B., Fombella-Blanco M. A., Fernández-González D., Valencia-Barrera R. M., 1996. The role of meteorological factors in determining the annual variation of *Alternaria* and *Cladosporium* spores in the atmosphere of Palencia, 1990-1992. Int. J. Biometeorol. 39: 139-142.

Hjelmroos M., 1993. Relationship between airborne fungal spore presence and weather variables. Grana, 32: 40-47.

Hyde H. A., Williams D. A., 1946. A daily census of *Alternaria* spores caught from the atmosphere at Cardiff in 1942 and 1943. Trans. Brit. Mycol. Soc. 29: 78-85.

Infante F., Dominquez E., 1988. Annual variation of *Cladosporium* spores in home habitats in Cordoba, Spain. Ann. Allergy 60: 256-261.

Kasprzyk I., Rzepowska B., Wasylów M., 2004. Fungal spores in the atmosphere of Rzeszów (South-East Poland). Ann. Agric. Environ. Med. 11: 285-289.

Katial R. K., Zhang Y. M., Jones R. H., Dyer P. D., 1997. Atmospheric mold spore counts in relation to meteorological parameters. Int. J. Biometeorol. 41: 17-22.

Kendrick K., 1990. Fungal allergens. [In:] Sampling and identifying allergenic pollen and moulds. E. G. Smith (ed.), Blewstone Press, San Antonio.

Konopińska A., 2004. Monitoring of *Alternaria* Ness and *Cladosporium* Link airborne spores in Lublin (Poland) in 2002. Ann. Agric. Environ. Med. 11: 347-349.

Lacey J., Pepys J., Cross T., 1972. Actinomyces and fungus spores in air as respiratory allergens. [In:] D. Shapton and R. Board (eds), Safety in Mycology. Soc. Appl. Bact. Techn. 6: 151.

Larsen L., Gravesen S., 1991. Seasonal variation of outdoor airborne viable microfungi in Copenhagen, Denmark. Grana, 30: 467-471.

Levetin E., Dorsey K., 2006. Contribution of leaf surface fungi to the air spora. Aerobiologia, 22: 3-12.

Licorish K., Novey H. S., Kozak P., Fairshter R. D., Wilson A. F., 1985. Role of *Alternaria* and *Penicilium* spores in the pathogenisis of asthma. J. Allergy Clin. Immunol. 76: 819-825.

Lopez M., Salvaggio E. J., 1983. Climate-Weather-Air pollution. [In:] Allergy: Principle and practice. E. Middleton, C. E. Reed & E.F. Ellis (eds), C.V. Mosby St. Louis-Toronto.

Lyon F. L., Kramer C. L., Eversmeyer M. G., 1984. Vertical variation of airspora concentrations in the atmosphere. Grana, 23: 123-126.

Méndez J., Iglesias M. I., Jato M. V., Aira M. J., 1997. Variación del contenido en esporas de *Alternaria*, *Cladosporium* y *Fusarium* en la atmósfera de la ciudad de Ourense (aňos 1993-1994). Polen, 8: 79-88.

Mitakakis T., Ong E. K., Stevens A., Guest D., Knox R. B., 1997. Incidence of *Cladosporium*, *Alternaria* and total fungal spores in the atmosphere of Melbourne (Australia) over 3 years. Aerobiologia, 13: 83-90.

Mitakakis T. Z., Clift A., McGee P. A., 2001. The effect of local cropping activities and weather on the airborne concentration of allergenic of *Alternaria* spores in rural Australia. Grana, 40: 230-239.

Munuera Giner M., Carrión Garcia J. S., 1995. Daily variations of *Alternaria* spores in the city of Murcia (semi-arid south-eastern Spain). Int. J. Biometeorol. 38: 176-179.

Munuera Giner M., Carrión García J. S., Navarro Camacho C., 2001. Airborne *Alternaria* spores in SE Spain (1993-98). Grana, 40: 111-118.

O'Hollaren M. T., Yunginger J. W., Offord K. P., Somers M. J., O'Connel E. J., Ballard D. J., Sachs M. I., 1991. Exposure to an aeroallergen as a possible precipitating factor in respiratory arrest in young patients with asthma. N. Engl. J. Med. 324: 359-363.

Palmas F., Cosentino S., 1990. Comparison between fungal airspora concentration at two different cities in the South of Sardinia. Grana, 29; 87-95.

Paredes M. M., Martinez J. F., Silva I., Tormo R., Muňoz A. F., 1997. Influencia de los parámetros meteorológicos en la dispersión de esporas de las especies de *Alternaria* Nees ex Fr. Boletin de Sanidad Vegetal Plantas, 23: 541-549.

Rapiejko P., Lipiec A., Wojdas A., Jurkiewicz D., 2004. Threshold pollen concentration necessary to evoke allergic symptoms. Int. Rev. Allergol. Clin. Immunol. 10 (3); 91-94.

Ricci S., Bruni M., Merigi M. G., 1995. Aerobiological monitoring of *Alternaria* fungal spores; a comparision between surveys in 1992 and 1993 and local meteorological condition Aerobiologia, 11: 195-201.

Rosas I., Escamilla B., Calderón C., Mosiňo P., 1990. The daily variations of airborne fungal spores in Mexico City. Aerobiologia, 6: 153-158.

Sakiyan N., Inceoğlu Ö., 2003. Atmospheric concentrations of *Cladosporium* Link and *Alternaria* nees spores in Ankara and the effects of meteorological factors. Turk. J. Bot. 27: 77-81.

Shaheen I., 1992. Aeromycology of Amman area, Jordan. Grana, 31: 223-228.

Srivastawa A. K., Wadhwani K., 1992. Dispersion and allergenic manifestations of *Alternaria* airspora. Grana, 31: 61-66.

Stennett P. J., Beggs P. J., 2004. *Alternaria* spores in the atmosphere of Sydney, Australia, and relationships with meteorological factors. Int. J. Biometeorol. 49: 98-105.

Stępalska D., Wołek J., 2005. Variation in fungal spore concentrations of selected taxa associated to weather conditions in Cracow, Poland, in 1997. Aerobiologia, 21: 43-52.

Stępalska D., Harmata K., Kasprzyk I., Myszkowska D., Stach A., 1999. Occurrence of airborne *Cladosporium* and *Alternaria* spores in Southern and Central Poland in 1995-1996. Aerobiologia, 15: 39-47.

Targonski P. V., Persky V. W., Ramekrishnan V., 1995. Effects of environmental molds on risk of death from asthma during the pollen season. J. Allergy Clin. Immunol. 95: 955-961.

Tariq S. M., Matthews S. M., Stevens M., Hakim E. A., 1996. Sensitization to *Alternaria* and *Cladosporium* by the age of 4 years. Clin. Exp. Allergy, 26: 794-798.

Troutt C., Levetin E., 2001. Correlation of spring spore concentrations and meteorological conditions in Tulsa, Oklahoma. Int. J. Biometeorol. 45: 64-74.

Zarodniki rodzaju *Alternaria* w aeroplanktonie i ich korelacje z czynnikami pogodowymi

Streszczenie

W wielu pracach dotyczących badań nad stężeniem zarodników rodzaju *Alternaria* w powietrzu pojawiały się różnego rodzaju analizy statystyczne opisujące charakter zależności pomiędzy stężeniem spor w powietrzu i czynnikami pogodowymi. W większości przypadków były to proste statystyki opisowe m.in. współczynnik korelacji Spearmana czy analiza regresji wielokrotnej.

W ciągu ostatnich kilku lat ukazało się kilka prac z prognostycznymi modelami statystycznymi (Szwecja, Grecja, Polska).

Statystycznie istotne, pozytywne korelacje były notowane dla dobowych temperatur maksymalnych i średnich a negatywne dla: wysokości opadów deszczu, ciśnienia atmosferycznego, temperatury punktu rosy i prędkości wiatru. Żaden z autorów nie zanotował istotnej statystycznie korelacji pomiędzy stężeniem zarodników rodzaju *Alternaria* a temperaturą minimalną.

Przy obecnym stanie badań nad relacjami statystycznymi pomiędzy obecnością (stężeniem) zarodników w powietrzu a czynnikami meteorologicznymi warto budować statystyczne modele prognostyczne, które dają bardziej precyzyjne informacje o badanych związkach i znacznie upraszczają prognozowanie sezonów zarodnikowania i konstruowanie kalendarzy dla lekarzy alergologów.