public are the pollen counts issued from the previous 24 hours and most of the time from a single sampling site in the city. In order to allow people to avoid times and places when allergens are present, it is of prime importance to improve knowledge of the spatial and temporal distribution of the pollen during the season.

Because anemophilous pollen grains are airborne, meteorological factors have a large impact on their dispersal. Different statistically based types of models tend to predict pollen concentrations from meteorological conditions as reported by Laaidi *et al.* (2003). Overall correlations can be established between concentrations and meteorological factors but this type of empirical approach does not provide any causal explanation for the day-to-day pollen variation. Current scientific efforts aim to develop source-oriented models using high-resolution meso-scale atmospheric models (*e.g.* Pasken *et al.*, 2002). In the present context, the research requires efficient physically-based approaches more complex than empirical-statistical techniques, in order to deal with the explicit simulation of atmospheric circulations, taking into account the modelling of aerosols that are transported in the flow, dispersed according to the source abundance and sedimented according to deposition processes. To account for pollen in regional climate models, several strategies can be selected depending on the objectives of the experiment, primarily dependent on the desired time space scales. The model used needs to reproduce current 3-D transport and patterns of concentration, including scavenging by precipitation and diurnal influences related to PBL characteristics.

The NARCM model developed at UQAM and previously applied to a number of climate-related studies (Laprise *et al.*, 1998), has been adapted specifically to pollen studies (Muñoz-Alpizar *et al.*, 2002). Its self-nesting option has also been used to downscale atmospheric flow to 1 km-scale (Goyette *et al.*, 2002). By adequately adjusting the scale of the region, it has been possible to obtain the necessary spatial coverage to address the issues related to pollen transport and dispersion. The RCM is now designed to simulate the aerobiological pathway at a 1-km resolution over the Greater Montreal area. The multiple nested grid starting from the largest scale, with a horizontal mesh of 49 km, covering several thousand km^2 is used in this study. Then, using roughly the same number of grid points (60 X 60) but with a much finer resolution, a zooming strategy is applied from grid 1 to grid 3 in order to target an area of the order of 100 x 100 km^2 with a grid resolution as high as 1 km. Recent experiments show that the patterns of ragweed concentrations simulated by the Canadian RCM are in good agreement with observations.

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Study of pollen production in six species of *Quercus (Quercus robur, Quercus pyrenaica, Quercus rubra, Quercus suber, Quercus ilex y Quercus faginea)*

Dacosta, N.; Rodríguez-Rajo, F. J.; Méndez, J. & Jato, V.

Department of Plant Biology and Soil Science, Faculty of Science of Ourense, University of Vigo, 32004 - Ourense (Spain).

Oak is the dominant tree in many of Europe's deciduous forests. In the regions of Northwest Spain *Quercus robur* L. is the representative of this genus that occupies the greatest geographical area. In Galicia, in

addition to this species, there are also *Q. pyrenaica* Willd. and, to a much more limited extent, *Q. ilex* ssp. *ballota* (Desf.) Samp. In Bol., *Q. suber* L and *Q. faginea* L.. There also exists the ornamental cultivation of American oak species: *Q. rubra* L. and *Q. palustris* Muenchn.

In addition to *Quercus* pollen's importance as a pollinosis agent, its study is also essential for evaluating the ecological conservation of Spain's woodland. Possible changes in the distribution or production of oak due to hotter spring temperatures or frost damages in recent years (JATO et al. 2002) are of great economic importance to the timber and livestock industries. Furthermore, in some areas its fruitage is used for breeding certain native species of animals (GARCÍA-MOZO et al. 2002).

Nowadays is of a great importance in phenological studies to know pollen production of trees. It gives us an idea of the quantity of pollen that the tree is able to produce in order to correlate this parameter with airborne pollen concentrations registered. There are few studies focused about *Quercus* genus' pollen production, and some of them agree that production varies according to the species, oscillating between 1.9×10^4 and 1.3×10^6 pollen grains per flower (MOORE & WEBB 1978, TORMO et al. 1996).

The objectives of this study are to know the pollen production of the six main *Quercus* species presents in the Northwest of Spain. The studied species were *Quercus robur, Quercus pyrenaica, Quercus rubra, Quercus suber, Quercus ilex* and *Quercus faginea*. As production protocol the HIDALGO et al. (1999) method was taking into account. Ten trees have been selected in each specie. In each one of them has been carried out a production study of pollen grains by anther, flower, catkin, tree and area. In the case of *Quercus ilex* and *Quercus faginea* due to the specimens are too young, it has not been carried out production/m^2, appearing the results as pollen grains/tree and pollen grains/catkin respectively.

Quercus rubra, with 697305 pollen grains, has been the specie with the highest value of pollen production by catkin followed by *Quercus pyrenaica, Quercus robur, Quercus faginea, Quercus ilex* and finally *Quercus suber* with 355236. In relation to pollen by tree production and pollen by square meter, the specie that has reached the highest records has been *Quercus robur* with $43{,}2 \times 10^{10}$ and $2{,}2 \times 10^{10}$ respectively.

GARCIA-MOZO, H.; GALÁN, C.; AIRA, MJ.; BELMONTE, J.; DÍAZ DE LA GUARDIA, C.; FERNÁNDEZ, D.; GUTIERREZ, M.; RODRÍGUEZ, FJ.; TRIGO, M.M. & DOMINGUEZ-VILCHES, E. (2002). Modelling start oak pollen season in different climatic zones in Spain. **Agricultural and Forest Meteorology** 110: 247-257.

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Session c5

APPLIED AEROBIOLOGY: AGRICULTURE

Forecasting olive (*Olea europaea* L.) crop yield based on pollen emission and floral phenology in Andalusia Region, Spain

Galán, C.[1]; García-Mozo, H.[1]; Vázquez, L.[1]; Ruiz, L.[2]; Díaz de la Guardia, C.[3] & Domínguez-Vilches E.[1]

[1] Department of Biología Vegetal, University of Córdoba, 14071 - Córdoba (Spain).
[2] Department of Biología Animal, Vegetal y Ecología, University of Jaén, 23071 - Jaén (Spain).
[3] Department of Biología Vegetal, University of Granada, 18071 - Granada (Spain).

Obtaining reliable crop estimations is an increasing necessity in order to achieve an optimised and effective agronomic management. Andalusia Region (Spain) is the largest olive oil producer in the world. In later years some attempts have been done in order to use pollen emission data as an indicator of fruit production in wind pollinated plants. Several studies have been carried out in different olive crop areas with promising results (GONZÁLEZ-MINERO et al., 1998; FORNACIARI et al., 2002 and GALÁN et al., in press). In the present work, an analysis of floral phenology, airborne pollen concentrations and meteorological data has been performed to develop olive production forecasting. The forecasting models have been established for the main olive crop areas in Central and Eastern part of the Andalusia Region. In decreasing order of area given over to olive crop they are Jaén, Córdoba and Granada provinces.

Four Hirst volumetric spore traps located at the city of Córdoba (37°50'N, 4°45'W), Priego de Córdoba (37°26'N, 4°11'W), Jaén (36°46'N, 3°47'W) and Granada (37°11'N 3°35'W) have been running from 1982 in Córdoba, 1992 in Granada and 1993 in Priego de Córdoba and Jaén. Floral phenological data have been taken at different longitude and altitude. Total olive fruit production data come from official sources of the Statistical Data Yearbook published by the Andalusia Regional Government. Meteorological data were supplied by the Spanish National Institute of Meteorology.

There is a flowering time lag from the lowest to the highest areas and from Western to Eastern part of the Region. Phenological data allowed us to determine which part of the pollen curve should be included in the models. As regards to the meteorological influence in fruit development, Rainfall and Maximum and Minimum Temperature during spring and autumn were the most important meteorological parameters affecting final fruit production, which takes place during winter. Nevertheless, statistical analyses revealed differences among the sites as regards the timing and the degree of influence of the meteorological parameters.

Integrating aerobiological, field phenological and meteorological data is an important tool to estimate olive crop production. The reliable results confirm the validity and accuracy of the worldwide used Hirst volumetric traps as a tool for olive crop yield forecasting in high density olive-growing areas. This would be an asset in enabling farmers and, overall governmental department, to improve plan market economies and to define a common agricultural policy among European Union countries.

FORNACIARI, M., PIERONI, L., ORLANDI, F. & ROMANO, B. 2002. A new approach to consider the pollen variable in forecasting yield models. **Economic Botany** 56(1): 66-72.

GALÁN, C., L., VÁZQUEZ, H. GARCÍA-MOZO & E. DOMÍNGUEZ. Forecasting olive (*Olea europaea*) crop yield based on pollen emission. **Field Crop Research** (en prensa).

GONZÁLEZ- MINERO, F.J., CANDAU, P., MORALES, J., TOMAS, C. 1998. Forecasting olive production based on ten consecutive years of monitoring airborne pollen in Andalusia (Southern Spain). **Agr Ecosyst Environ** 69:201-215.

Aerobiology applied to olive yield forecasting in Italy

Orlandi, F.; Lanari D.; Romano, B. & Fornaciari, M.

Department of Plant Biology and Agroenvironmental Biotechnology, University of Perugia,
Borgo XX Giugno 74 - 06121 Perugia Italy.

The main objective of this study was to investigate the relationships between pollen emission and fruit production in Olea *europaea* L. considering fifteen olive monitoring stations located in regions of Southern Italy (Sicily, Puglia, Calabria and Campania) which account together for 90% of the total olive oil italian production.

The climate heterogeneity among different areas does not allow us to investigate the phenomena by the "technical pooling" but the geographical segmentation was necessary.

In the past, only the climatic variables were used in the implementation of statistical crop forecasting models, while successively the complexity of the problem induced to consider contemporary traditional statistical analyses (agro-meteorological models) with more recent methodologies such as the aerobiological one which, in anemophilous species, may carry out fundamental information on the flowering phenomenon. Some multi-year studies on olive and grape have demonstrated that there is a close relationship between the quantity of pollen released during flowering and fruit production (Fornaciari et al. 2002; Galan et al. 2003; Pieroni et al. 1998). Many efforts have been made to interpret the pollen variable in greater detail by elaborating indexes more and more efficient respect to the final production. We considered first the summation of the daily pollen concentrations in the pollen emission period (Ip), then the contracted Pollen Index (Ipc) by excluding the final flowering phase. Successively, in a recent study, we have utilized an optimised pollen index (Ipo) which makes more parsimonious and efficient the statistical modelling for predicting olive production (Orlandi et al. 2004).

In this empirical study the pollen monitoring investigation was carried out to analyse the olive pollination over a 5-year period (1999-2003) for the fifteen south Italy areas. Volumetric pollen traps were used to determine pollen release (mean daily pollen concentrations) and flowering trends in the olive groves. The pollen trap developed from the Hirst model is capable to intercept airborn material from an average radius of about 10 Km. By knowing the aspirated volume of air, which is constant, the concentration of particles/m^3 can be expressed for hourly, daily or weekly intervals.

Non parametric estimations were used to calculate the pollen index which was more efficient in explaining the crop production. The best pollen fit during flowering was reconstructed for each station trough the density function of the empirical distribution probability. The selected climatic variables, obtained from the Italian Central Office of Ecology, were minimum/maximum temperature and rain sub-divided into 10-day periods from January 1 until anthesis dates. The estimation of the forecast model was made by pooled and panel data approach. The main usefulness of the panel data lies in the possibility of giving two kinds of information in cross-sectional time-series data: the cross-sectional data reflected in the differences between the fifteen stations in the south of Italy, while the time series data reflected in the changes within stations over the five years considered. Statistical results evidence Ipo as a biological indicator, which characterizes the dynamics of the flowering phase, and as a validate instrument to forecast olive harvest. The statistical analyses evidence the climate variables linked to rain and minimum temperature in the summer period as those more correlated to the biological process.

FORNACIARI, M., PIERONI, L., ORLANDI, F., ROMANO, B. 2002. A new approach to consider the pollen variable in forecasting yield models. **Economic Botany**. 56(1): 66-72.

GALAN, C., VAZQUEZ, L., GARCIA-MOZO, H., DOMINGUEZ, E. 2003. Forecasting olive (Olea *europaea* L.) crop yield based on pollen emission. **Field Crops Research**. Article in press.

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Analysis of *Olea europaea* L. pollen productivity in Jaén (southern Spain): Historic development and future forecast

Ruiz, L.[1]; Díaz de la Guardia, C.[2]; Cano, E.[1] & Alba, F.[2]

[1] Department of Animal Biology, Plant Biology and Ecology, Science Faculty,
University of Jaén, 23071 - Jaén, Spain.
[2] Department of Botany, Science Faculty, University of Granada, 18071 Granada, Spain.

Jaén province (south-eastern Iberian Peninsula) holds the largest area of olive tree crop in the world. Its Mediterranean climate, optimal for this crop, along with the subsidiary policy of the European Union have allowed a spectacular increase of the surface devoted to this crop, especially during the nineties. These factors nowadays result in an cultivated area larger than 553 000 hectares, which represents 22% of the province surface and more than 90% of the total cultivated area. Ten years of continual aerobiological monitoring (1994-2003), according to the Hirst methodology and the samples analyses protocols adopted by the Spanish Network of Aerobiology, have made clear that every spring the inhabitants of this province are exposed to an extremely high amount of airborne pollen belonging to *Olea europaea* L.. At present, it is possible that at a worldwide scale these may be the highest concentrations of pollen having a notable allergenic activity.

The aerobiological control in the atmosphere of Jaén has revealed that during the *Olea europaea* main pollination period the daily pollen concentrations easily reach 5 000 grains/m^3. In the last five years this number has been frequently overcome to such an extent that levels of more than 10 000 grains/m^3 have been sporadically reported. In fact, the average annual increase of collected pollen during the last five years is about 45% larger than that in the first five years.

It is well known that annual variations in total pollen productivity and emission from source to atmosphere are closely related to environmental conditions, especially to the thermo-pluviometric ones. In the case of olive crop previous rainfall plays a determinant role in flower production and therefore in pollen production. Our results have confirmed this fact. However, rainfall can not explain all the differences among the annual amount of collected pollen, since the pollen concentrations have increased through the years, while the rainfall shows a more or less random pattern. As the pollen source is a cultivated plant, we must consider anthropozoogenic factors as the ultimate cause for this phenomenon. From this point of view, the area of olive tree crop in Jaén has increased in the 90s at a rate of more than 5 500 hectares per year, which means about 55 000 more hectares in the producing source area. The largest part of this increase has taken place in the lowlands of the Guadalquivir Valley, where soils are very suitable for its cultivation. The homogeneous climatic conditions in the whole area significantly favour the phenological synchronization of the crop. But which has turned out significant for the flowering and pollen production increase has been the transformation of olive tree crops into irrigated cultivations. In the early 90s it was rarely found irrigated lands, whilst nowadays between 20% and 30% of the olive crops in Jaén are periodically supplied with water. This allows the trees to produce abundant flowering every year, instead of an alternated yearly pattern of lower and higher flowering and therefore crop production.

Faced with the increasingly trend in the irrigated crop areas we can expect the olive flowering and pollen production in Jaén province to maintain at extremely high levels, regardless of the previous climatic conditions. It is even possible a slight increase in the future.

Development of an Automatic Corn Pollen Monitor for environmental assessment of genetically modified crops

Kawashima, S.[1]; Fujita, T.[2]; Matsuo, K.[1]; Shibaike, H.[1]; Du, M.[1]; Inoue, S.[1] & Yonemura, S.[1]

[1] National Institute for Agro-Environmental Sciences 305-8604 Tsukuba (Japan).
[2] Yamato Engineering Company Ltd. 238-0013 Yokosuka (Japan).

With the safety and impact on the environment of transgenic crops becoming issues of concern, Losey et al. (1999) identified the possibility that pollen from Bt (*Bacillus thuringiensis*) corn could kill untargeted insects. On the other hand, there is a gene flow problem that is dispersal of artificially modified gene to the natural environment by airborne pollen. Especially for corn that is a typical wind-pollinated crop, there is a possibility that pollen diffuses considerably widely depending on meteorological conditions. The number of pollen grains decreases in exponential form according to the distance from the source field, and the extent of dispersal is controlled greatly by meteorological conditions and the state of flowering of the plant. It is necessary to develop a suitable automatic measurement technique for the pollen in order to deal with these problems appropriately.

We developed an automatic monitoring device that is easy and a continuous measurement can be taken for airborne corn pollen. The past methods, both the gravity method and the volumetric method, are done by counting the number of adhering pollens on glass slides, and require a large input of time and labour using the microscope. The automatic corn pollen monitor is constructed with semiconductor laser technology.

Experiments were carried out in the field of the National Institute of Agro-Environmental Sciences in Tsukuba city. Durham type pollen samplers were set up in the cornfield, and the meteorological observation was done at the same time. The developed corn pollen monitor was set up in the cornfields, and observation was continued through the flowering season. Two pollen monitors were used for the observation. Large conic glass (100mm diameter) was installed in the air-intake part of one monitor. A small conic glass (65mm diameter) was installed on the other monitor.

The semiconductor laser of wavelength 780nm makes a beam in the seat of about 30μm in thickness through a cylindrical lens and collimate lens. The scattered light corresponding to the particle size is caused when the particle enters from the nozzle, and the scattered light is detected with detecting element (PIN-PD). We aimed to develop a design that would select globular particles using the width of the detected pulse, and the side and forward scattered intensity of scattered light. Some of the air exhausted from the pump circulates, and the air that contains pollen is sucked in and wrapped, and it passes through an optical detector (air jacket method). This method prevents dirt from getting in to the optics, and improves the response of detector circuit to the pollen. The flowing quantity was set to be 4.1 litres per minutes, which is less than half the Burkard type sampler.

The counts of the airborne pollen grains from the corn pollen monitor were compared to the counts of pollen grains from a Durham sampler that was set up adjacent to the pollen monitor. The correlation coefficient between the counts from the pollen monitor (large intake) and the Durham method was 0.949, and the correlation coefficient between the counts from the pollen monitor (small intake) and the Durham methods was 0.928. For either combination, very high correlation coefficients were obtained. It is understood that the corn pollen monitor explains 89% of the change measured by the Durham method based on the contribution ratio (square of the correlation coefficient).

The diurnal change in the airborne corn pollen count was quite clear on both abundant pollen days and more scarce pollen days. The peaks are clearly evident. The changing pattern of the amount of airborne pollen shows a characteristic shape that peaks in daytime, and becomes almost zero at nighttime. The changing pattern has a different shape from those of the meteorological elements such as air temperature or wind speed.

There is a peak in the morning every day, which decreases to less than half of the peak density at noon. The density decrease after the peak until nighttime is gradual, although the density increase after sunrise is sudden. A large amount of pollen is emitted when the air temperature rises rapidly.

LOSEY, J.E., RAYOR, L.S. & CARTER, M.E. 1999. Transgenic pollen harms monarch larvae. **Nature**. 399: 214.

Session c6

APPLIED AEROBIOLOGY: CULTURAL HERITAGE

Aerobiology in museums: comparison between sampling methods

Caneva, G.[1]; Nugari, M. P.[2]; Romolaccio, M.[1] & Zuccarello, V.[3]

[1] Dipartimento Biologia, Università di Roma Tre, 00146 Roma, Italy.
[2] Istituto Centrale Restauro, 00184 Roma, Italy.
[3] Dep. Scienze e Tecnologie Biologiche e Ambientali, Univ. Lecce, Italy.

Biological aerosol can be a factor inducing biodeterioration of materials in museums and in other indoor spaces, when the environmental conditions are favourable. The estimation of microbial contaminations can vary in relation to differences in sampling methods. A comparison between data obtained with passive sedimentation methods and active impactor samplers (Andersen cascade sampler) was made in two different rooms of the Doria Pamphilj Gallery (Roma) during different seasons. The results obtained were comparatively analysed on the basis of daily and seasonal data. Two matrices of 16 taxa, with 48 and 16 relieves for the two rooms, corresponding to 12 days of sampling (3 for each season), were elaborated after a previous mathematical transformation for the statistical comparison Multivariate analysis for the presence/absence, ordinal (V abundance classes) and quantitative data was compared using the Goodall probabilistic index (Goodall et al. 1987, Goodall and Feoli 1991). The most frequent (more than 70%) isolated genera were *Aspergillus, Alternaria Cladosporium, Penicillium* and *Micelia sterilia,* with a minimum of one up to 8 different species. Differences in quantitative values of biological aerosol were observed during the seasons with highest values in spring. The different methodology for sampling does'not seem clearly to affect the biodiversity. The results can be summarised as following: the two sampling methodologies show more or less small differences, especially in the case of daily data; these differences lower in the case of average seasonal data; the transformation of data in classes of abundance is the best method for data comparison; the sampling with the Andersen method better estimates the species with smaller spores with respect to the passive sedimentation method and reduces the entity of taxa with higher spores.

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