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Simulations of Pollen Transport by Wind

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[This contribution is a summary of ongoing research into pollen transport by wind. A more detailed summary may be found at http://www.sgr.org.uk/GenEng/ChardonSummPollen.html. A full report will appear on this web-site shortly. Two papers on which this contribution is based will be submitted to a peer-reviewed journal. E. Novotny is Co-ordinator for GM Issues at Scientists for Global Responsibility.]

The main points of this work are as follows:

1) Pollen deposition is highly non-uniform, even if the wind is steady and uniform. 'Fingers' and 'islands' characterise the area of deposit, which is thus very patchy. This unevenness of deposit makes it difficult to set a firm distance beyond which the level of deposition can be confidently expected to remain below a given percentage.

2) Setting separation distances between crops to avoid contamination is further complicated by the fact that the distance to which pollen is carried increases with the strength of the wind.

3) As is shown by the observational work of others, pollen drifts down to earth from higher altitudes; and the level of deposition/fertilisation remains substantial even at very large distances from the source. These large values have been observed even in the upwind direction from the source.

With the use of a Cellular Automaton model, we have simulated the creation, release, transport by wind and deposition of pollen originating in a field containing a single type of crop. Numerical experiments have been made with one or more of various components of wind, such as a steady and uniform wind, eddies, wavelike progressions, cyclic reversals and gusts. The results have been illustrated in contour plots of density of deposited pollen and of air-borne pollen remaining at the end of the computer run. As expected, stronger winds carry pollen to greater distances than light winds. Even in a uniform wind, however, the pollen deposit is not uniformly distributed: ‘fingers’ and ‘islands’ of high pollen density are present. A sample of these results is shown in the Plates (which are here not numbered consecutively).

These simulations are carried out in dimensionless variables, which can be converted to physical variables by assigning physical dimensions to the dimensionless units, such as the time interval between successive ‘snapshots’ of the moving pollen and the size of the cell in the lattice representing the source field and surroundings. An important parameter is probability of deposition, which is not an empirically measured quantity. We have, however, made numerical experiments using a variety of values for this quantity to compute the percentages of pollen deposited at various distances from the source. Comparing these results with an exponential decline obtained from published observations, we found that only a limited range for probability of deposition produces a good fit to the exponential profile. Choosing values in this range, we have then been able to produce results similar to the observations of Jones and Newell [1] and, after introducing a scheme to calculate fertilisation when two kinds of pollen are present, we were also able to produce models that approximate the measurements of Jones and Brooks [2]. The latter authors observed the percentage of hybridisation at various distances from a source field containing yellow maize, from which the pollen blew onto eight blocks of white maize at various distances from the field of yellow maize. When calculating models to be compared with the observations of Jones and Newell and of Jones and Brooks, we represented the wind speed and direction as a function of time by approximations to data provided by the Meteorological Office. The generally good agreement between our models and field observations leads us to believe that our models provide realistic representations of actual pollen flow and deposition, even though not all the input parameters are measured quantities. We emphasise that, whether or not the actual values we have used for these parameters are correct, the qualitative conclusions of our work, listed at the beginning of this contribution, will remain valid.

At large distances from the source, observed values of pollen deposition tend to level off, rather than to continue to decline towards zero. We have not modelled this observed effect, which evidently arises from transport of pollen at higher altitudes with subsequent drifting down to earth. A hint of this phenomenon is visible in the observations of Jones and Brooks [2] when displayed in logarithmic form. It is distinctly present in the observations made in the Northern Caucasus of the U.S.S.R. by Salamov, cited by Jones and Brooks. Salamov found large percentages of outcrossing of maize, despite the fact that his measurements were made in the direction opposite to that of the prevailing wind. At large distances, his values were:

Distance	400	500	600	700	800	metres
Percentage of outcrossing	0.02	0.08	0.79	0.18	0.21	

Even at more than half a kilometre, the level was comparable to the permissible level of GM contamination being proposed for non-GM crops. On the downwind side of the source field, the outcrossing must have been much greater.

Further details may be found at www.sgr.org.uk, under ‘Genetic Engineering’ and, on that page, under ‘Listing of Chardon LL’, Report III - A Model for Pollen Transport by Wind. At present, only a summary is available; but the full report will appear shortly. Two papers on which this contribution is based will be submitted to a peer-reviewed journal.

REFERENCES

[1] Jones M.D., Newell L.C. 1946 University of Nebraska College of Agriculture, Agricultural Experiment Station, Research Bulletin No **148**
[2] Jones M. D., Brookes J.S. 1950 Oklahoma Agricultural Experimental Station Technical Bulletin No **38**

PLATES

Each successive colour in these Plates represents (a range of) pollen densities that are roughly twice as great as those represented by the preceding colour.

Plate 3 compares the effects of different wind strengths and of the size of the field.
(a) A wind that is steady and uniform over the lattice blows down the length of the lattice. The wind speed is w = 0.4. (b) The size of the field has been doubled, but the wind speed is the same as in (a). (c) The size of the field is again the standard size, as in (a), but the wind speed has been doubled to w = 0.8.
As the field size is increased, the amount of pollen produced and carried by the wind is also increased. The corresponding increase in deposited pollen is not easily discernible in a comparison of (a) and (b) (owing to the low value of P_{sE}), but the greater amount remaining air-borne is clearly visible. As the wind-speed is increased, the pollen is deposited farther down the lattice, as expected from dimensional analysis.

Plate 6 incorporates changes in the side-wind that are random in both place and time.
(a) Again there is a steady, uniform down-wind of speed w = 0.8; but the side-wind now varies randomly at each time-step and at each cell of the lattice. It may assume any of the values +a, 0, -a, i.e., up, zero, down. The value of a in this case is 0.2.
(b) This case is similar to (a) but with a = 0.4.
(c) This case is similar to (a) but with a = 0.8.
As expected, the stronger the side-wind, the greater is the transverse dispersal of the pollen. Essentially, this random transverse effect produces a transverse diffusion.

Plate 7 illustrates the effects of gusting winds.
Frame (a) shows a comparison case which takes account of pollen transport by an irregular wind, involving the following components: (1) a component independent of space and time; (2) a wavelike, propagating component of zero average over space and time, which is here given by a complicated expression represented by a Fourier series; and (3) a randomly fluctuating component of zero average. No gusty component is included.
(b) In addition to the irregular wind of (a), a gust blows obliquely across the lattice. The peak of the gust occurs at time-step t = 200, with diminishing effectiveness at times before and after t = 200. These gusts disperse the pollen more widely in the transverse direction than do the irregular winds (a).bbbbbbbbbv