Integrating the biological and physical components of maize pollen dispersal

Mark Westgate, Ray Arritt, and Susana Goggi
Iowa State University
Biological and Physical Components of Out-crossing

- **Biological (source)**
  - Pollen shed characteristics
    - Timing, intensity, viability
- **Physical (delivery system)**
  - Topography
    - Distance, elevation, wind breaks, border rows
  - Atmospheric conditions
    - Wind speed, wind direction, stability index, mixing height, air temperature, relative humidity
- **Biological (receiver field)**
  - Pollen shed characteristics
  - Synchrony with female and adventitious pollen source
  - Specific combining ability
Structure of pollen production, dispersal, and out-crossing model
Pollen production

Crop Data

Pollen Shed

Weather Data

Meteorological Analysis or Model

Pollen Transport

Receptor Risk

Topographic Data

Pollen Viability
• Pollen shed characteristics
  • Timing, intensity, viability

Timing of pollen shed can be simulated from tassel development and population dynamics.
Diurnal patterns of pollen shed vary

Temp, RH, and wind speed affect the initiation and intensity of pollen shed
Shed typically begins at RH < 90%
Pollen dispersal

- Crop Data
- Weather Data
- Topographic Data
- Pollen Shed
- Meteorological Analysis or Model
- Pollen Transport
- Pollen Viability
- Receptor Risk
- Pollen Viability

The diagram illustrates the various components involved in pollen dispersal, including data sources and models that contribute to understanding pollen transport and viability, leading to risk assessment.
• **Physical (delivery system)**
  
  – **Topography**
    - Distance, elevation, wind breaks, border rows
  
  – **Atmospheric conditions**
    - Wind speed, wind direction, stability index, mixing height, air temperature, relative humidity

*Adapted from Di-Giovanni and Kevan, 1991*
Pollen transport models

• Lagrangian random-walk approach
  – the pollen cloud is represented as a population of virtual “particles”
  – each virtual particle can be traced according to its source, path, or other property of interest

• Gaussian plume approach
  – the pollen cloud is ‘constrained’ to a normal distribution that is modified hourly by local atmospheric conditions
Physical parameters for modeling maize pollen dispersal are fairly well established

-- weight/grain: 250 to 350 ng
-- diameter: 50 to 90 µM
-- density: 1.25 to 1.45 g cm$^{-3}$
-- settling velocity: 20 – 32 cm s$^{-1}$
-- number per plant: 0.5 to 6 x 10$^{6}$
-- duration of shed: 4 to 6 days
Field evaluation of the pollen transport models:

- 9 monitoring locations within the source field
- Receptors (sticky traps) placed at 5, 10, 30, 90, 165, 330, and 660 feet from the edge of the source field in the 8 major directional axes
- Pollen dispersal monitored from 0730 to 1700 hours.
Daily and seasonal patterns of pollen dispersal from a source field can be simulated fairly accurately.
...but both models tend to overestimate deposition near the source field, and underestimate deposition at greater distances from Riese, 2004.

Values summed for eight cardinal directions from source field.

Need to account for modification of the 3D flow field by the crop (windbreak) and atmospheric turbulence on a larger scale (large eddy simulation).
Pollen viability decreases linearly with moisture content.

Pollen of the ‘average’ maize genotype loses viability completely at about 30% moisture

Average values for 11 genotypes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial viability</td>
<td>80%</td>
</tr>
<tr>
<td>PMC at 0%</td>
<td>30%</td>
</tr>
<tr>
<td>Pollen/tassel</td>
<td>3.1E6</td>
</tr>
</tbody>
</table>
Loss of pollen moisture is an exponential function of VPD and time.

\[ PMC = 63.2 e^{-0.0012 \text{VPD} t} \]

\( r^2 = 0.86 \)

*Field

\* Aylor 2003*
“Terminal viability” of lofted maize pollen

- Pollen lofted through two representative atmospheric soundings (updraft at 3 m/s, fall at 20 cm/s)

- Viability adjusted accounting for VPD through the profile until the pollen grain returned to the ground.

Brunet et al., 2004

Figure 3. Vertical variation in viability: mean values and standard deviations over all complete flights. The curve is an exponential adjustment through the experimental points.

Y-axis normalized to daily convective boundary layer, 800-2000m
Out-crossing

- Crop Data
- Pollen Shed
- Weather Data
- Meteorological Analysis or Model
- Pollen Transport
- Topographic Data
- Pollen Viability
- Receptor Risk
• Biological (receiver field)
  – Pollen shed characteristics
  – Synchrony with female and adventitious pollen source
  – Specific combining ability

“Nick Manager” converts daily estimates of pollen shed and silk emergence to simulate kernel set for any given field condition.

Temporal profile of silk exertion (blue), temporal profile of pollen shed (black), and simulated daily values of kernel set (red).
Simulated kernel set in 13 seed production fields

Fonseca et al. (unpublished)

Loss of pollen viability and pollen trapping by leaves not taken into account
3-year seed industry study

About 50% of the mid-field samples were free of out-crosses

A few mid-field samples had > 10% out-crosses

Ireland et al 2004
Risk of Out-crossing

Field B
Risk Index: 5.68

Field C
Risk Index: 4.65

Early and late appearing silks at risk

Late appearing silks at risk
An example of simulated out-crossing resulting from “adventitious presence” late in flowering.

**Nick Manager Summary**

- Total kernel production: 21.8 mil kernels/ha
- 76.5% silks were pollinated
- 98.4% genetically pure seed
- 1.6% out-crossed seed

Adventitious pollen peaked at 7.5 gr/cm² on 216.
Contamination by Pollen Movement

Seed Field West Source

Durant, IA :1998

July

12 14 16 18 20 22 24

East Pollen
Seed field silking
Seed field pollen
West Pollen

WindRose for Durant, IA
15-21 July 1998: 0800 – 1400 h

Percent Out-crossing

2.0 2.0 0.0 0.25

Seed Field

Inter-industry Isolation Standards Study