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Dermot Hayes is a native of the Republic of Ireland. He obtained a Bachelor of Agricultural Science degree from University College in Dublin in 1981. He entered the Ph.D. program in the Department of Agricultural Economics at Berkeley in the fall of 1981, where he majored in International Trade. Dr. Hayes joined the Department of Economics at Iowa State University in March 1986. His research interests include food safety, livestock modeling, demand analysis, commodity markets, and agricultural and trade policy.

Dermot is currently the Pioneer Hi-Bred international chair in Agribusiness, a Professor in the Department of Economics, and a Professor in the Department of Finance at Iowa State University. He is currently in charge of the public policy task force at the Plant Science Institute at ISU.

Economic Cost Associated with Pollen Flow From Transgenic Crops

Presented by Dermot Hayes
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Co-authors and funding

- David Ripplinger, Kendall Lamkey, Mark Westgate
- Containment task force (BIGMAP), Science and Society and Plant Science Institute

Motivation

- Recent Cases of Contamination and Near Contamination
 - Starlink 2000
 - Prodigene 2002
- Industry Concern
 - North American Millers Association
 - BIO

Conceptual issues and solutions

- A large number of possible avenues for contamination
 - Solution: we focus on an avenue (pollen drift) that exists in the Cornbelt and not in other states
 - We assume that weather stations are used in the source fields
- A zero tolerance is inconsistent with probability theory
 - Solution: We use tolerances

Conceptual issues and solutions

- “Harm” is difficult to define, most antibodies are safe for human consumption and detection is close to impossible
 - Solution: We define harm as the possibility of contamination
- The wind conditions that cause one pollen to move will also cause others to move, this breaks the link between probability and the level of contamination
 - Solution we measure the probability that tolerance levels are exceeded

Conceptual issues and solutions

- The average consumer overestimates small probabilities
 - Solution we express tolerances in terms of kernels per forty acre field, there are 540 million kernels in a forty acre field ($90,000 * 150 * 40$)
- We do not know which direction the wind will blow
 - We conservatively assume that wind always blows in the direction of the field of interest

Conceptual issues and solutions

- It is conceptually difficult to trade off risk against economic benefit
 - Solution we express the risk as the fair value of an insurance product that fully indemnifies the owner of the target field
- The failure levels for biological controls is not known with precision
 - Solution we assume a failure level of 1 in 100 for detasseling and male sterility

Phases of Research

- Pollen dispersal model
- Calibration
- Insurance pricing mechanism

Stochastic Modeling of Dispersion

- Description of wind behavior
- Lagrangian stochastic (LS) model
- Monte Carlo Simulation

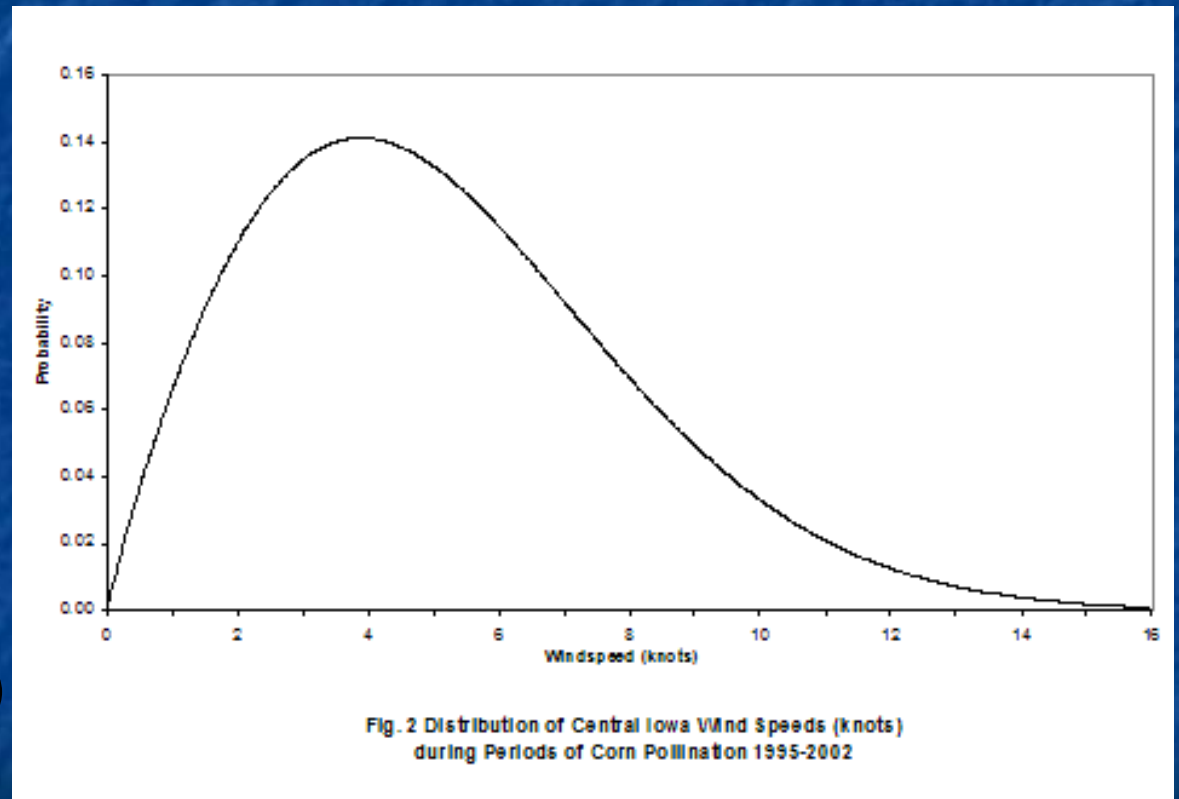
Stochastic Modeling of Dispersion: Weibull Model of Wind Distribution

- Weibull is most common distribution used to model wind speeds (Seguro and Lambert)
- Parameters, c and k , are estimated using maximum likelihood techniques.

$$P(u < u_i < u + du) = P(u > 0) \left(\frac{k}{c}\right) \left(\frac{u_i}{c}\right)^{k-1} \exp\left[-\left(\frac{u_i}{c}\right)^k\right] du$$

Insurance Policy: Fitting Local Wind Behavior to the Weibull Distribution

- Wind data from Boone, Iowa
- Collected during period of maize pollination (Miller)



Stochastic Modeling of Dispersion: Lagrangian Stochastic (LS) Model

- LS model closely follows that of Aylor
- Models movement of pollen in vertical direction (z) and horizontal direction (x)

$$dX = udt$$

$$dZ = (W - v_s)dt$$

$$dW = \left[-\frac{b_w^2}{2\sigma_w^2}W + \frac{1}{2} \frac{\partial \sigma_w^2}{\partial z} \left(\frac{W^2}{\sigma_w^2} + 1 \right) \right] dt + b_w d\xi_w$$

Parameter Values

- Available from Literature
 - Displacement level and roughness length for fallow, corn, and soybeans
 - von Karman's constant and settling velocity of corn pollen

Stochastic Modeling of Dispersion: Deposition and Temporal Conditions

- Pollen is considered viable for 2 hours

$$Q_T = \{Q_R(0, H, 0) : Q_R(x, z_o, t), t \leq 7200\}$$

- Probability of pollination is the ratio of transgenic pollen to all pollen deposited

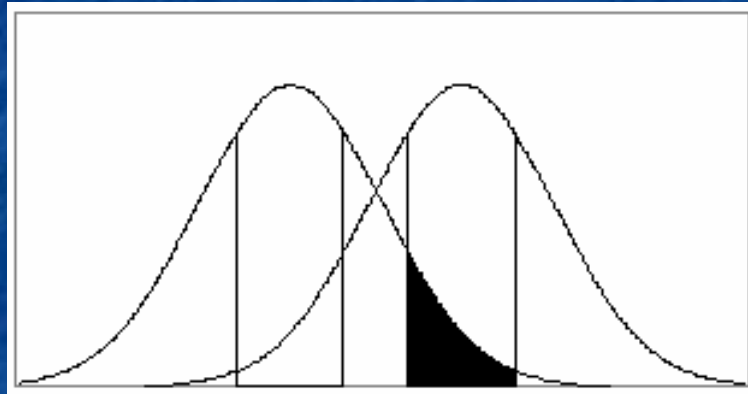
$$P = Q_T / Q_A$$

Stochastic Modeling of Dispersion: Physical & Biological Inhibitors of Gene Dispersal

- Physical methods
 - Bagging
 - Detasseling
- Biological methods (Daniell)
 - Male sterility

Stochastic Modeling of Dispersion: Contemporaneous Fertility

- Using corn silking as a proxy, determined probability of fields separated by time of planting sharing a period of fertility



- Probability of fields separated by 28 days or more sharing a period of fertility was less than one percent

Stochastic Modeling of Dispersion: Probability of Zero Contamination

- The probability that long distance pollen will succeed in fertilizing is the ratio of transgenic pollen, Q_T , to all pollen present, Q_A , times the probability that genetic seepage occurs, P_S , times the probability that the plots are fertile at the same time, P_F .

$$P = P_F \left(\frac{P_S Q_T}{Q_A} \right)$$

- The probability of *any* contamination occurring, P_C , approaches 1 as the number of size of production grows:

$$P_C = \left(1 - (1 - P)^K \right)$$

Calibration

- Model is calibrated using field data collected by Mark Westgate et al. during July 2000
- Gathered weather data including wind speed from station located in center of source plot
- Gathered and measured pollen daily from passive collectors located in eight directions at varying distances from source each day

Calibration Process

- Estimated deposition using LS model using characteristic wind speed for each day
- Since actual amount of pollen is not known, deposition ratios are used with the first site of collection normalized to one

Calibration results for a wind speed of two miles per hour

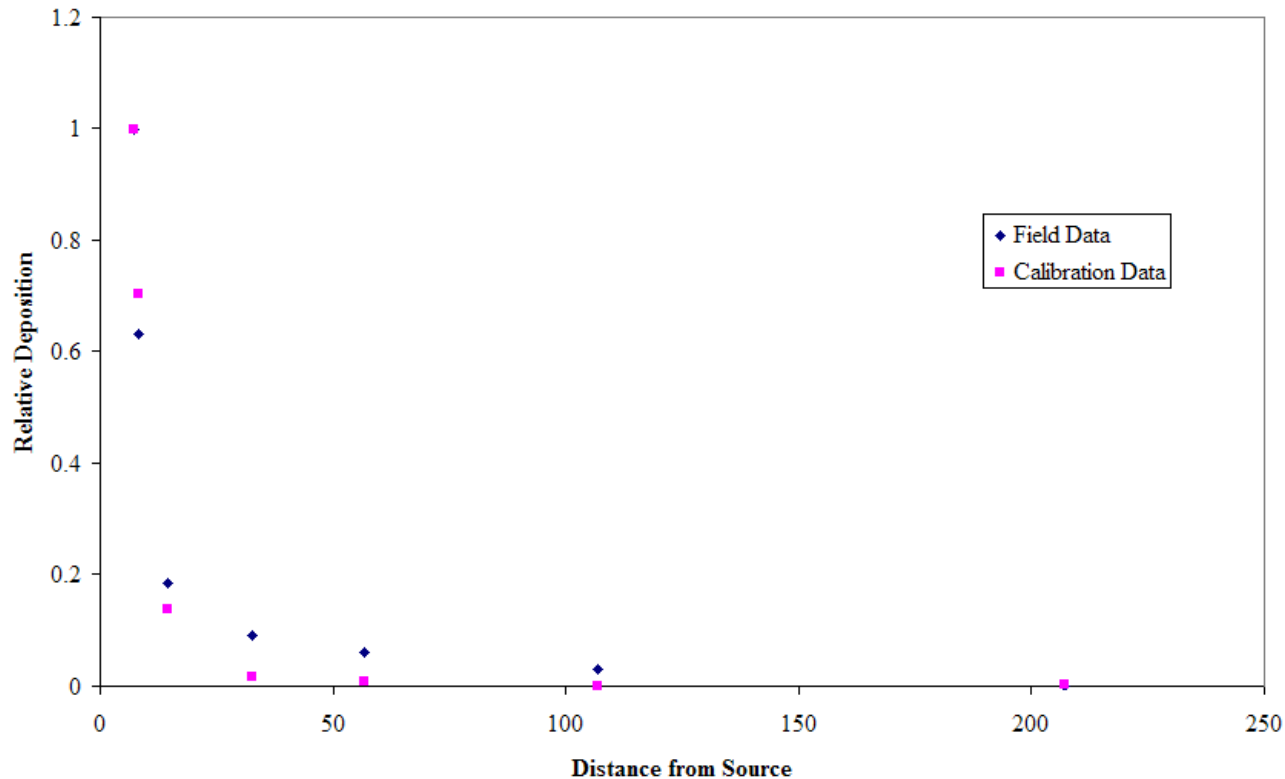


Figure 1. Relative Deposition of Pollen

Calibration Results

- Model overestimated pollen deposition near the source and at furthest distance
- Calculated results can be seen as a higher bound on actual values, i.e. they are conservative

APHIS Production Guidelines

- Controlled Pollination (bagging or detasseling)
 - Corn allowed from $\frac{1}{2}$ to 1 mile if planted 28 days before or after pharmaceutical corn
- Uncontrolled Pollination
 - No corn allowed within one mile
- Either case
 - 50 feet adjacent to pharmaceutical plot must be left fallow
 - No restrictions beyond 1 mile

Long Distance Pollen Dispersal

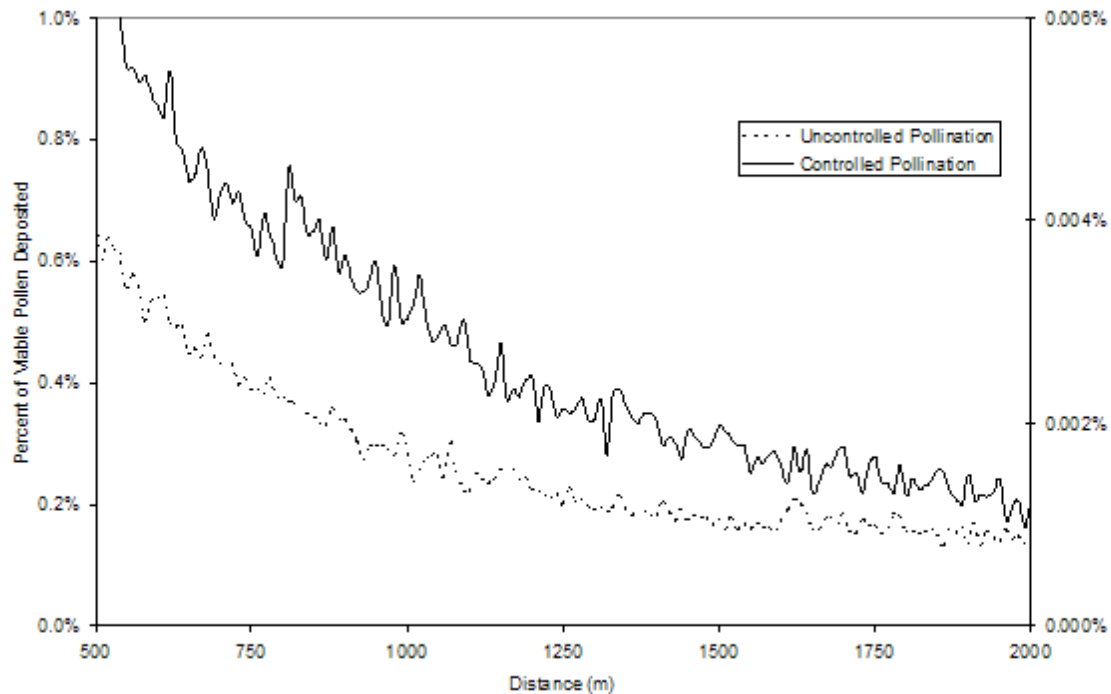


Figure 3. Long Distance Pollen Dispersal

Insurance Policy: Assumptions and Parameters

- Assumptions
 - Size of fields
 - One acre pharmaceutical field
 - 40 acre conventional corn fields
 - One-percent failure rate of detasseling/bagging and biological mechanism
- Exogenous Parameters
 - Price: \$2.00/bu.
 - Yield: 150 bu./acre
 - Social tolerance level

Insurance Policy: Results

Table 1. Cost of Insuring against Genetic Contamination in Dollars per Acre

Tolerance (kernels/field)	Controlled Pollination			Uncontrolled Pollination		
	Field 1	Field 2	Field 3	Field 1	Field 2	Field 3
100	-	-	-	0.06999	-	-
50	-	-	-	0.50643	0.18869	-
10	-	-	-	2003.43	1730.43	1042.8
5	0.00039	-	-	4268.859	4092.583	4006.853
1	11.52838	0.13745	-	4359.427	4179.914	4049.519
0.5	17.87641	9.22446	0.92088	4313.94	4224.184	4075.309

Insurance Policy: Results

- Insurance premiums are calculated in a very conservative way (detasseling and biological inhibitor, wind direction and calibration)
- With a tolerance level of one kernel per forty acre field the fair cost of the insurance product is \$11.50
- Cornbelt Policy makers need to compare this cost against the economic benefits of the field
- Larger scale production of pharmaceutical corn will result in lower premiums as relatively less pollen will escape from the field

Summary

- Constructed a pollen dispersal model and calibrated it against data
- Calculated the fair value of an insurance policy that indemnifies against contamination
- Model is extremely flexible and can address different production scenarios, assumptions