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Annexe to the Response to the GM Science Review – First Report, by Scientists for Global Responsibility

Report by Dr Eva Novotny 5 November 2003

Separation Distances Between Fields of Maize of Different Varieties Required to Avoid Contamination Above Allowed Limits

I. Introduction

The GM Science Panel has accepted as 'robust' the separation distances required between maize crops as presented in a report by J. Ingram (2000) for the Ministry of Agriculture, Fisheries and Food.[1] Ingram states that his calculations were based on the experimental work of Jones and Brooks (1950)[2] but gives no indication of how the calculations were made, or which of the data of Jones and Brooks were used or what allowances, if any, were made for conditions unlike those prevailing during the experiments.

This Annexe examines Ingram's data and re-calculates some of his values. The large extrapolations from the small blocks of maize in the experiments of Jones and Brooks to the large fields for which Ingram calculated his values render the separation distances unreliable, as **the extrapolations can far outweigh the contributions of the known data.** However, no experimental data that would be more suitable are available. The important effects of high winds have evidently not been included in Ingram's work.

New calculations for deriving separation distances for maize, without a barrier, are presented, and the method by which these were obtained is explained in detail. The results are not dissimilar to those obtained by Ingram, indicating that the additional factors mentioned in our response to the GM Science Panel First Report have not been included and that therefore the separation distances set are too small.

Although graphs and tables of intermediate calculations are not included here, they can be supplied upon request.

These results indicate that the issue of separation distances needs to be re-examined, and that new experimental data are essential before this is done.

II. Contents

Section III describes the experimental data of Jones and Brooks
Section IV examines Ingram's results and finds inconsistency in some of the values.
Section V discusses the assumption of exponential decline.
Section VI explains the method used to obtain the present results.
Section VII compares Ingram's results with the new results.
Section VIII presents the conclusions of this Annexe.
Section IX makes a final comment.

III. The Experimental Data of Jones and Brooks

The experimental procedure of Jones and Brooks was described in a paragraph appearing in our response to the GM Science Review First Report, and it this paragraph is reproduced below.

The experiments of Jones and Brooks
Little research has been done to measure the decline in levels of deposited pollen or of hybridisation as a function of distance from the source field, but useful experiments were carried out by Jones and Brooks more than 50 years ago.[3] They were performed in 'a rolling area' near Stillwater, Oklahoma during the seasons of 1947, 1948 and 1949. The source of pollen was a field of yellow maize with one side facing blocks of size 100 feet square, positioned at various distances from the large field and growing maize of a white variety. The blocks appear to have been arranged in staggered positions so as not to block the wind from the source field. Prevailing winds come from the south and southwest, and the blocks are located to the north of the source field. Pollination of the white variety by the yellow maize resulted in a yellow kernel, which was easy to detect amidst the neighbouring white kernels. This experiment therefore provided a simple way to find the percentage of outcrossing at various distances from the source field.

IV. Ingram's results for average percentage of outcrossing over the extended portion of the field

The method Ingram used to calculate his table was not described. Ingram did state that he used the experimental data of Jones and Brooks. The experimental blocks receiving pollen were, however, much smaller than the depths of the fields considered by Ingram. It is therefore necessary to extrapolate the experimental data beyond the extent of the blocks. It was not stated which of two possible data sets was chosen by Ingram from amongst Jones and Brook's work. What can easily be calculated by use of Ingram's table and Jones and Brook's data for either case is the average percentage of outcrossing in the extended portions of the fields, for either orientation of the fields.

A. Recipient fields assumed by Ingram

Ingram calculated the separation distances required between a field that is a source of pollen and each of two fields of different sizes, each in either of two orientations. The sizes are 2 ha and 5 ha, both with sides in the ratio of 4:1. They are assumed to have either the long side or the short side facing the source field. Their dimensions are:

Field of 2 ha = 70.71 m x 282.8 m
" " 5 ha = 110.80 m x 447.2 m

J&B used blocks of 25 or 24 rows of maize, spaced 3.5 ft apart. They were said to be 100 ft square, or 30.5 m x 30.5; however, they seem actually to have been a little smaller:

Block of 25 rows has depth = 24 x 3.5 feet = 25.60 m
" " 24 " " " = 23 x 3.5 feet = 24.54 m

To find how far the extrapolations from J&B's blocks to Ingram's fields must be carried, the dimensions of Ingram's fields can be expressed in units of one block:

Field of 2 ha has dimensions = 2.76 x 11.05 (blocks of 25 rows)
= 2.88 x 11.53 (blocks of 24 rows)

Field of 5 ha has dimensions = 4.37 x 17.47 (blocks of 25 rows)
= 4.56 x 18.23 (blocks of 24 rows)

Very large extrapolations, between nearly 3 times and in excess of 18 times, are seen to be required.

B. Calculation of the average percentage of outcrossing over the extension of the field beyond the depth of Jones and Brook's block

Let p_1 = average percentage of outcrossing over one block as measured by Jones and Brooks

p = average percentage of outcrossing over the extension of the field beyond one block

P = Ingram's tabulated value = average percentage of outcrossing over the entire field

L = depth of field = length of field measured in direction away from the source field

Then

$$P = [p_1 + p\,(L-1)]\,/L$$

and

$$p = (PL - p_1)/(L-1).$$

This formula for p is used to calculate the table below.

Table of p, the average percentage of outcrossed maize over the extension of the field beyond one block, using Jones and Brooks's data for 1949

1949

Separation Distance (rods)	(m)	Long side facing 2 ha	Long side facing 5 ha	Short side facing 2 ha	Short side facing 5 ha
0 rods =	0 m	3.96	4.47	2.57	1.69
5	25	2.12	2.61	1.72	1.17
15	75	1.54	1.60	1.01	0.75
25	125	1.26	1.27	0.75	0.53
40	200	0.165	0.41	0.30	0.24
60	300	0.051	0.135	0.155	0.142
80	400	0.15	0.18	0.145	0.13
100	500	0.054	0.087	--	--

C. Comments on Ingram's results

The table for 1949 has an inconsistency at D = 40 rods (200 m) and at D = 60 rods (300). While other tabular entries are lower in the case that the short side of the field is facing the source field, these two cases imply that the amount of outcrossing has *increased* beyond the distance equivalent to the length of the short side. This is not realistic.

V. Assumption of Exponential Decline

To provide a basis for making extrapolations over the field, we adopt an exponential form for the decline of outcrossing with distance from the source. This form is often assumed for the decline, up to a distance beyond which the levels fluctuate but do not systematically decline over the distances at which measurements have been made.. This portion of the curve will be called the 'tail'. While an exponential function is not an altogether accurate representation of the curve of decline, it serves as a useful tool.. The function is applicable if a uniform and steady wind carries pollen at uniform density. In this case, a small 'absorption' of pollen takes place as it travels a short distance, such that the two quantities are proportional. This relation can be expressed as a differential equation, which, when integrated, yields an exponential function.

Care must be taken that the exponential decline is not carried beyond the distance at which the tail of the distribution should be adopted. It is not possible to determine accurately from J&B's tables the average value about which fluctuations occur at large distances, but these data suggest that 0.10 might be a reasonable value to assume for the present work.

It is assumed, in accordance with the findings of Jones and Brooks, that pollen blowing in from the sides of the recipient field may be neglected. Thus only the distance measured along the perpendicular to the facing edge of the source field needs to be considered.

VI. Procedure Used Here to Re-calculate Separation Distances

A. Fitting of an exponential curve

i. The percentage p_o of outcrossing at the last point of a block (*i.e.*, at the last row or group of rows, according to the data-set used) was identified, by eye estimate*, on a graph plotting the data for each block.

ii. This value was multiplied by e, the base of natural logarithms, and the row-number or group-number, as appropriate, at which the percentage p of outcrossing reaches this value, as judged by eye estimate, was noted. Thus

$$p_e = e\, p_o.$$

The distance between the abscissa of the last point (at which percentage $p = p_o$) and the abscissa of the point at which $p = p_e$ is, by definition, one scale-length l_o for that curve.

iii. If l denotes the abscissa, measured from the point at which $p = p_o$, then the exponential curve representing the graph is

$$p = p_o.\ \exp(-l\,/l_o). \qquad (1)$$

iv. To test whether the curve conforms to the observations, additional points have then been added to the graph by the use of this relation,.

* A procedure exists for applying the method of least squares to find corrections to an exponential function that approximates observed points; but the considerable labour of applying it does not seem justified for the present purpose.

v. To test the effect of a change in l_o, the average value of l_o over all blocks was then used to re-calculate the positions of the additional points.

vi. To test the effect of a change in p_o, a new value should be assumed and the preceding steps should be repeated for some of the graphs. This has not been done.

B. Extrapolation over Ingram's fields

i. For each table, the distance l_t (measured from the end of the J&B block, where $p = p_o$) at which p reaches the level p_t of the tail is found from equation (1). If this value is less than the distance to the far end of the field in question, the constant value $p = p_t = 0.10$ must be assumed over the remainder of the field..

The sensitivity of the final results to the value assumed for the constant level of the tail should be ascertained. This has not been done here. In view of the large extrapolations, the value assigned to p_t needs careful consideration.

ii. The total percentage of outcrossing over the extension of the field is next found. Integration of equation (1) is performed with respect to distance l, from the end of J&B's block, where $l = l_o$, to the distance l_{end}, which is the lesser of either the end of Ingram's field, l_{Ing} or the distance l_{tail} at which p becomes less than p_t. The integration yields the total percentage P of outcrossing over that range:

$$P = \int p_o \exp(-l/l_o)\, dl$$

$$= p_o\, l_o\, [1 - \exp(-l_{end}/l_o)]$$

If the tail is reached within the field, *i.e.*, if $l_{tail} < l_{Ing}$, then integration over the tail yields simply the area of the rectangle between the distances l_{tail} and l_{Ing} and with upper bound 0.10.

iii. The total percentage over the block of J&B is found as the average percentage over the block, as given by J&B's table, multiplied by the number of rows or groups of rows in the block, as appropriate.

iv. The average percentage of outcrossing over the whole field is determined as the sum of the total percentages over the block and over the entire extension, divided by the total number of rows or groups of rows that would occupy the entire field at the same spacing as in J&B's block..

VII. Comparison of the new results with those of Ingram

The table below presents the new results, based on the 1949 data set of Jones and Brooks, together with the values given by Ingram.

Calculations are made for two cases for each field: long side facing the source field, and short side facing the source field. The data from 1949 were chosen for this table because they agree more closely with Ingram's values that do the data for the average of 1948 and 1949, which was the only alternative.

Average percentage of outcrossing over the whole field, based on 1949 data

The first of each pair of entries is the new result of this Annexe; the second entry is the value from Ingram's table. Blank entries indicate that the data showed large scatter.

		Long side facing				Short side facing			
Separation Distance		2 ha		5 ha		2 ha		5 ha	
0 rods =	0 m	15.6	14.0	9.92	10.70	4.0	5.2	3.3	3.4
5	25	9.5	8.3	6.0	6.4	2.5	3.3	2.7	2.2
15	75	4.0	4.1	2.5	3.2	1.1	1.7	1.2	1.2
25	125	1.9	2.1	1.2	1.8	0.5	1.0	0.65	0.70
40	200	1.2	1.0	0.78	0.88	0.4	0.5	0.45	0.37
60	300	0.54	0.39	0.38	0.33	0.21	0.23	0.28	0.19
80	400	-	0.21	-	0.21	-	0.16	-	0.14
100	500	-	0.15	-	0.14	-	-	-	-

VIII. Conclusions

The table above shows that the new values are similar to those calculated by Ingram. This agreement indicates that no allowance was made for factors influencing the deposition of pollen, such as wind velocity; and no extra margin of safety was applied.

It would be desirable to determine the sensitivity of these results to the values adopted for representing certain parameters of the data. This has not been done.

It must be stressed that the final results presented here do not allow for factors such as high winds, which would have considerable influence on the values found. The possibility of obtaining information on winds and weather conditions during the time and near the place where the observations were made is being investigated.

This work makes clear the need for more experimental data, including weather data during the time of the pollination, and a re-calculation of separation distances.

IX. A Final Comment

The MAFF report prepared by J. Ingram gives no indication of how the table of percentage of outcrossing at various distances from the source field was obtained, apart from the statement in the caption to the table that the values were ‘calculated using the data of Jones and Brooks’. In an age when scientists have been vilified and even dismissed from their posts for disclosing results in advance of peer review, it is astonishing that the government should have accepted a report presenting results that are not even capable of peer review, for lack of information as to how they were obtained.

[1] J. Ingram, July 2000, Report prepared for the Ministry of Agriculture, Fisheries and Food, Project No. RG0123, National Institute of Agricultural Botany, 'Report on the separation distances required to ensure cross-pollination is below specified limits in non-seed crops of sugar beet, maize and oilseed rape'; appearing as Annex 1 of 'Review of the use of separation distances between genetically modified and other crops', 3 August 2000, Ministry of Agriculture, Fisheries and Food.

[2] Melvin D. Jones and James S. Brooks, July 1950, Oklahoma Agricultural Experiment Station, Technical Bulletin No. T-38.

[3] Melvin D. Jones and James S. Brooks, July 1950, Oklahoma Agricultural Experiment Station, Technical Bulletin No. T-38.