# THE EFFECTS

OF

# CROSS AND SELF FERTILISATION

IN THE

# VEGETABLE KINGDOM.

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age, were subjected from first to last to the same conditions, and were descended from the same parents. When only from two to six pairs of plants were measured, the results are manifestly of little or no value, except in so far as they confirm and are confirmed by experiments made on a larger scale with other species. I will now give the report on the seven tables of measurements, which Mr. Galton has had the great kindness to draw up for me.

"I have examined the measurements of the plants with care, and by many statistical methods, to find out how far the means of the several sets represent constant realities, such as would come out the same so long as the general conditions of growth remained unaltered. The principal methods that were adopted are easily explained by selecting one of the shorter series of plants, say of *Zea mays*, for an example."

*Zea mays* (*young plants*).

| As recorded by Mr. Darwin. | | | Arranged in Order of Magnitude. | | | | |
|---|---|---|---|---|---|---|---|
| | | | In Separate Pots. | | In a Single Series. | | |
| Column I. | II. | III. | IV. | V. | VI. | VII. | VIII. |
| | Crossed. | Self-fert. | Crossed. | Self-fert. | Crossed. | Self-fert. | Difference. |
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| Pot I. | 23 1/8 | 17 3/8 | 23 1/8 | 20 3/8 | 23 1/8 | 20 3/8 | −3 1/8 |
| | 12 | 20 1/8 | 21 | 20 | 23 1/8 | 20 | −3 1/8 |
| | 21 | 20 | 12 | 17 3/8 | 23 | 20 | −3 |
| | | | | | 22 1/8 | 18 5/8 | −3 1/4 |
| Pot II. | 22 | 20 | 22 | 20 | 22 1/8 | 18 5/8 | −3 1/4 |
| | 19 1/8 | 18 1/8 | 21 1/4 | 18 5/8 | 22 | 18 1/8 | −3 3/8 |
| | 21 1/8 | 18 5/8 | 19 1/8 | 18 1/8 | 21 1/8 | 18 | −3 1/8 |
| | | | | | 21 1/4 | 18 | −3 1/4 |
| Pot III. | 22 1/8 | 18 1/4 | 23 1/8 | 18 1/4 | 21 | 18 | −3 |
| | 20 1/8 | 15 1/8 | 22 1/8 | 18 | 21 | 17 1/8 | −3 1/8 |
| | 18 1/8 | 16 1/4 | 21 1/8 | 16 1/4 | 20 1/8 | 16 1/4 | −3 7/8 |
| | 21 1/8 | 18 | 20 1/4 | 16 3/8 | 19 1/8 | 16 1/8 | −2 7/8 |
| | 23 1/8 | 16 1/8 | 18 1/8 | 15 1/8 | 18 1/8 | 15 1/4 | −2 7/8 |
| | | | | | 12 | 15 1/8 | +3 1/8 |
| Pot IV. | 21 | 18 | 23 | 18 | 12 | 12 1/8 | +0 1/8 |
| | 22 1/8 | 12 1/8 | 22 1/8 | 18 | | | |
| | 23 | 15 1/4 | 21 | 15 1/4 | | | |
| | 12 | 18 | 12 | 12 1/8 | | | |



"The observations as I received them are shown in columns II. and III., where they certainly have no *primâ facie* appearance of regularity. But as soon as we arrange them in the order of their magnitudes, as in columns IV. and V., the case is materially altered. We now see, with few exceptions, that the largest plant on the crossed side in each pot exceeds the largest plant on the self-fertilised side, that the second exceeds the second, the third the third, and so on. Out of the fifteen cases in the table, there are only two exceptions to this rule. We may therefore confidently affirm that a crossed series will always be found to exceed a self-fertilised series, within the range of the conditions under which the present experiment has been made.'

| Pot. | Crossed. | Self-fert. | Difference. |
|---|---|---|---|
| I. | 18 7/8 | 19 3/8 | +0 3/8 |
| II. | 20 3/8 | 19 | −1 3/8 |
| III. | 21 1/8 | 16 7/8 | −4 3/8 |
| IV. | 19 3/8 | 16 | −3 3/8 |

"Next as regards the numerical estimate of this excess. The mean values of the several groups are so discordant, as is shown in the table just given, that a fairly precise numerical estimate seems impossible. But the consideration arises, whether the difference between pot and pot may not be of much the same order of importance as that of the other conditions upon which the growth of the plants has been modified. If so, and only on that condition, it would follow that when all the measurements, either of the crossed or the self-fertilised plants, were combined into a single series, that series would be statistically regular. The experiment is tried in columns VII. and VIII., where the regularity is abundantly clear, and justifies us in considering its mean as perfectly reliable. I have protracted these measurements, and revised them in the usual way, by drawing a curve through them with a free hand, but the revision barely modifies the means derived from the original observations. In the present, and in nearly all the other cases, the difference between the original and revised means is under 2 per cent. of their value. It is a very remarkable coincidence

that in the seven kinds of plants, whose measurements I have examined, the ratio between the heights of the crossed and of the self-fertilised ranges in five cases within very narrow limits. In *Zea mays* it is as 100 to 84, and in the others it ranges between 100 to 76 and 100 to 86."

"The determination of the variability (measured by what is technically called the 'probable error') is a problem of more delicacy than that of determining the means, and I doubt, after making many trials, whether it is possible to derive useful conclusions from these few observations. We ought to have measurements of at least fifty plants in each case, in order to be in a position to deduce fair results. One fact, however, bearing on variability, is very evident in most cases, though not in *Zea mays*, viz., that the self-fertilised plants include the larger number of exceptionally small specimens, while the crossed are more generally full grown."

"Those groups of cases in which measurements have been made of a few of the tallest plants that grew in rows, each of which contained a multitude of plants, show very clearly that the crossed plants exceed the self-fertilised in height, but they do not tell by inference anything about their respective mean values. If it should happen that a series is known to follow the law of error or any other law, and if the number of individuals in the series is known, it would be always possible to reconstruct the whole series when a fragment of it has been given. But I find no such method to be applicable in the present case. The doubt as to the number of plants in each row is of minor importance; the real difficulty lies in our ignorance of the precise law followed by the series. The experience of the plants in pots does not help us to determine that law, because the observations of such plants are too few to enable us to lay down more than the middle terms of the series to which they belong with any sort of accuracy, whereas the cases we are now considering refer to one of its extremities. There are other special difficulties which need not be gone into, as the one already mentioned is a complete bar."

Mr. Galton sent me at the same time graphical representations which he had made of the measurements, and they evidently form fairly regular curves. He appends the words "very good" to those of Zea and



Limnanthes. He also calculated the average height of the crossed and self-fertilised plants in the seven tables by a more correct method than that followed by me, namely, by including the heights, as estimated in accordance with statistical rules, of a few plants which died before they were measured; whereas I merely added up the heights of the survivors, and divided the sum by their number. The difference in our results is in one way highly satisfactory, for the average heights of the self-fertilised plants, as deduced by Mr. Galton, is less than mine in all the cases excepting one, in which our averages are the same; and this shows that I have by no means exaggerated the superiority of the crossed over the self-fertilised plants.

After the heights of the crossed and self-fertilised plants had been taken, they were sometimes cut down close to the ground, and an equal number of both weighed. This method of comparison gives very striking results, and I wish that it had been oftener followed. Finally a record was often kept of any marked difference in the rate of germination of the crossed and self-fertilised seeds,—of the relative periods of flowering of the plants raised from them,—and of their productiveness, that is, of the number of seed-capsules which they produced and of the average number of seeds which each capsule contained.

When I began my experiments I did not intend to raise crossed and self-fertilised plants for more than a single generation; but as soon as the plants of the first generation were in flower I thought that I would raise one more generation, and acted in the following manner. Several flowers on one or more of the self-fertilised plants were again self-fertilised; and several