Art. 42.—*Natural Self-fertilization of Wheat on a Large Scale.*

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The area devoted to selection of pure strains of wheats at Lincoln College covered, in 1920, about 22 acres. Among these were six plots each about half an acre in extent, occupied by three pure strains of the variety known in New Zealand as White Straw Tuscan, a wheat closely allied to or identical with the Bellevue de Talavera of Europe. It is an early-maturing variety, coming into flower and ripening about a fortnight before the other varieties commonly grown.

In January, 1921, when they were nearly ready to cut, the plots were gone through for the purpose of picking out accidental impurities, this work embracing the roguing of intruding varieties, and in addition the roguing of any intruding strains of the same variety. It was at this stage that the fact became obvious that these three strains, G2, F8, and F10, were no longer pure, but included many strains—so many that it was not only impossible to pick out all the impurities, but, in one case, to tell which was the strain intended to be occupying the plot. It was at first thought that this was the result of accidental admixture of strains during the preceding harvest, where some ten Tuscan strains were grown side by side in the same field. But reflection on the care with which the harvest had been conducted, and on the very large number of the impurities, caused a search to be made for other explanations of the mixture of strains.

It was recalled that before the preceding harvest—that is, in December, 1919—a severe frost had damaged the wheats in the plots, and that the Tuscans, owing to their earliness, were the only ones that suffered, the yield of the strains of this variety being reduced from an estimated 60 to an actual 25 bushels per acre. None of the other varieties was frosted, and there were no marked impurities in their offspring in the succeeding year. It was taken as an hypothesis that the frost of December, 1919, had been just severe enough to kill the anthers of certain of the florets, but to leave the ovaries uninjured, so that if those ovaries developed at all they would have to be cross-fertilized, and that chiefly with pollen from their own or neighbouring strains of Tuscan, this being the only variety freely in flower within a fortnight of the time of the frost.

There were three ways of testing this hypothesis :—

(1.) To examine the mixed strains and see if their differences were such as to suggest cross-pollination between two strains of the same variety. This examination supported the hypothesis. The differences were very slight, and often elusive; they depended largely upon differences in times of ripening, and were often difficult to distinguish from variations induced by external conditions. Unfortunately, all the supposed pollen parents were not available for comparison, a number of strains grown in 1919 having been rejected and so not grown in 1920.

(2.) If the crops of 1920 had been grown from cross-fertilized seed, then the crop would represent the F_1 of a breeding-scheme, and there should be only as many types as there were parents, and that only where the male carried some dominant, affecting the appearance of the ripening plant. As a matter of observation, there were apparently some six or eight types in each of the plots, which would agree with the expectation

of the hypothesis. But the seed from this crop should show extensive variation. If any particular head were an impurity all its seeds should produce like plants; if it were a cross-bred its seeds might be expected to produce plants varying *inter se*. This was tested by taking twenty-five heads of the most varying appearances from each of the three strains and growing them in head-to-row plots. At the time of writing,* these plots are just ripening, and it is apparent that the variants selected last year were of three different classes:—

(*a*.) Accidental impurities—in which all the plants of the row are alike but are not Tuscans of the type of the plot from which they were selected.

(*b*.) Variants due to differences in soil or situation—in which all the plants of a row are alike and belong to the strain from which they were selected.

(*c*.) Natural crosses—in which the plants in a row vary *inter se*. In most of the cases the crosses are with other types of Tuscan, but in three rows the cross is with another variety that was grown in the same field.

The following table shows the number of each class of variants selected from each of the three strains:—

Strain.	Impurities.	Non-congenital Variations.	Crosses.	Totals.
G2	3	2	20	25
F8	3	13	9	25
F10	2	10	11	25

It was the strain G2 which in the roguing of last harvest appeared most heterogeneous, and this is reflected in the large number of proved crosses. In strain F8 a small number of crosses appears, and large a number of the variants selected were due merely to external conditions. This is reflected in the rather remarkable fact that, of the twenty-five rows of this strain, twelve contained plants affected with loose smut (from one to five plants per row of fifty plants), while in the other two strains no single smutted plant appeared. None of the wheat was pickled before sowing. Thus strain F8 is a smut-liable one, and the inheritance of this character indicates that the heads selected were of one strain—*i.e.*, the differences were accidental—the conclusion independently reached by an examination of the rows.

(3.) The third method of testing the hypothesis was to attempt to repeat the conditions and see if the supposed results were again obtained. The minimum temperature on the grass at Lincoln on the night of the frost was known, and Mr. Skey, of the Magnetic Observatory at Christchurch, twelve miles away, was able to provide a thermogram of the air-temperature in a shade-box on the night in question. From these two data an estimate could be made of the varying temperatures and their duration to which the frosted wheat had been exposed. Tuscan wheat was grown in pots at Lincoln, and when near flowering was removed to the garden of the freezing-works at Islington, where the New Zealand Refrigerating Company had arranged to produce such temperatures as were desired, Mr. A. M. Wright, chief chemist, and Mr. Piper, chief engineer, undertaking personal supervision of the experiments. When the anthers in the

* The completion of the paper was delayed for some weeks to allow almost complete ripening of the wheats under observation.

earlier florets of any particular set of plants were ripe but not extruded, six pots, containing about eighteen wheat-heads, were removed to the cooling-chambers. Four different series of temperatures were tried, each on six pots of wheat, the last one being as follows: The external air was at 50° F., and the pots were placed in a chamber 60 ft. by 24 ft., with a temperature of 36° F. During a period of six hours the temperature was gradually lowered to 26° F., and held there for two and three-quarter hours. The plants were then immediately removed to the open air, whose temperature was 60° F. After three days the florets were opened, and it was found that in the eighteen heads examined 16 per cent. of the florets had the anthers killed and the ovaries apparently unharmed. The anthers were withdrawn down and around the ovary, so that at first they escaped observation altogether. The filaments were found to be shrivelled, and the pollen-grains were fluid. The stage of development of the anthers appeared to be of importance, because it was usually in the central floret of the spikelet that the injury had occurred. In the remaining 84 per cent. of the florets the anthers were apparently uninjured.

The other series of temperatures which did not lead to the killing of anthers and also left the ovaries uninjured were as follows:—

(*a*.) Reduce from 39° to 29° in six hours, hold at 29° for two and three-quarter hours, and then raise gradually to 39° during the course of one hour, and then to open air at 60°. Result—plants wholly uninjured, due doubtless to the gradual thawing. (*b*.) The same as above, but at all points 3° F. lower—*i.e.*, minimum at 26° F., gradual rise. Result—all plants uninjured. (*c*.) The same as above, but all temperatures 3° lower still—*i.e.*, minimum at 23° F.; but in this case all plants were removed suddenly from the minimum temperature to the open-air temperature at 60° F. Result—all plants killed, anthers and ovaries; and in the majority of cases the glumes as well.

It was as a result of the failure in these three cases—(*a*), (*b*), and (*c*)—that the final and fairly successful series of temperatures recorded in paragraph (3) above was selected.

In this final case the florets in which the anthers had been killed were marked on the glumes with Indian ink, and the plants placed in the middle of a plot of Velvet wheat, some of whose anthers were then extruded. The Velvet wheat is so named from a velvety covering of hairs on the glumes, a character which proves to be dominant. The grains in the frost-esmasculated florets have developed and are nearly ripe in 70 per cent. of cases, and it is clear that these must have been cross-fertilized, if not by the Velvet wheat, at least by different florets of their own heads. The seeds will be sown and the proportion of Velvet crosses recorded.

It is clear, then, that frost of a certain intensity can lead to the cross-fertilization of wheat on a large scale, and this is one cause of the occurrence of new varieties.

It may be that artificial crossing of wheats can be more rapidly carried out by killing the anthers by freezing than by the usual method, but this would need suitable cooling-apparatus. Where this is available the plan would be to freeze the plants to some temperature like that above described, then tie the heads in paper bags with heads of the variety designed for the male parent, which should have, if possible, some easily recognized dominant character. On sowing all the seeds that ripen, those that have been crossed will produce plants showing the dominant, and will be kept, while those that are selfed will not show the dominant character, and will be pulled out and rejected.