

THE IMPORTANCE OF MAINTAINING A CONSTANT ELIMINATION FACTOR IN ASSOCIATION WITH A CONSTANT NUTRITION FACTOR IN PLANT BREEDING

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I shall not at this time present statistical data on the subject matter of this preliminary note. It is given at this time merely as a suggestion. It is a feature which, perhaps, every plant breeder has had fairly well in mind, though he may not have been thinking of it in the same manner or along the same lines. It is evidently the thought of almost all workers in cropping and plant breeding work that an experiment in testing out varieties or strains in a comparative way has little value unless the various conditions of cropping are reasonably similar for the tests or trials which are to be compared. Naturally this thought has caused those who are engaged in breeding work to give reasonable emphasis to preparing conditions of cropping which shall be rather uniform. However, most plant breeding work, and more especially in cereal crops, has been conducted with but slight concern as to the factors mentioned in the title of this paper. The reverse is, perhaps, more often the case than otherwise. Most agronomists and plant breeders, especially of cereals, have followed rather persistently—indeed, the writer thinks, quite too persistently—the old theory that best results may be gained by placing the seed under trial conditions of the most favorable sort for the development of an all-round plant; that is to say, they have usually prepared garden conditions upon which to develop a strain or variety; conditions which they believe will furnish all of the most desirable food relations for the particular crop. That is, conditions which appear to them apt to furnish the most satisfactory arrangement of all the ordinary nutrition factors. Even then, it can, perhaps, quite truly be said that in most cases such tests have been seldom twice on the same soil. Often the investigators seem interested in giving the seed a change of soil, as though they might fail of variation if this change of soil were not available. Indeed most such workers contend that under soils of most fertile and varying character the crop is most liable to vary from the type under consideration. The writer has not believed that these supposed ideal conditions are the most satisfactory under which to conduct breeding operations and selecting

operations with cereal crops, and, as has been reported elsewhere, has, for a number of years, been working with the point in view of developing conditions adverse to the supposed best cropping conditions. For example, instead of making studies upon variation of wheat, flax, and other cereals under the most satisfactory conditions of soil fertilization, soil cultivation, and crop rotation, many of the trials have been conducted upon and under conditions of continuous cropping of the soil by the same crop and under conditions in which certain definite modifications are maintained.

The gardens have been kept in the same place, but definite changes have been made in the conditions of certain beds. Always, however, the attempt is made to retain for a series of years one or more factors as constants. The particular variety is also tried under normal cropping conditions and under a number of other trial conditions for purposes of comparison. It has been the thought of the author that no matter in what manner variation may arise so that new characters become apparent, these new characters have, at some time, had to arise because of changed conditions or changes in conditions to which the parent plants have been subject, and it has been my belief that features of environment which involve the presence or absence of constant factors in nutrition have much to do with any changes which may take place, whether we speak of them as "fluctuating variations" or as apparently "fixed mutations." This would indicate that the writer has not seen sufficient evidence to prove that so-called unit characters or the elementary species of the Mendelian school do not vary as in the case of any other of the less "segregated" or *rather less apparent* types. It would also indicate that the author is not convinced that so-called acquired characteristics are not, under certain conditions, heritable.

Indeed these considerations prompt the writing of this short note. The writer thinks he has seen in his study of pure-bred types of flax and of wheat indications of changed character which must be inherited from year to year, which features of accumulated character could not have been observed had it not been possible to introduce a constant feature of elimination. The writer believes that whatever our investigations finally center upon as the real cause of the origin of immunity or resistance to diseases it will eventually be found that such immunity or resistance has been transmitted—inherited in exactly the same sense as any other character which reproduces itself in a morphological or physiological form. It would appear to have been shown by Biffin and others that such resistance to disease tends to

follow the so-called Mendelian laws of dominance and recession. Our own experiments in cross-breeding flax and growing upon flax-sick ground seem to bear out that conclusion, for flax is a closely inbred plant, and the writer has never seen any good evidence that a pure variety ever crosses in nature. Wheat also is a closely inbred plant, and the author has never seen, to his knowledge, a clearly proven case of cross-breeding in nature, though I admit freely that it seems strange indeed that such fine opportunity is given for the interbreeding of such plants and I would not assert that it never does take place. Possibly the time may come when we may have clear evidence that such crossing does take place in nature. Even then these observations will scarcely have lost bearing or importance, for an accumulative quality is apparently transmitted in the cross-breeding. The writer conducts a few experiments in cross-breeding every year, and very extensive experiments in selection with a view of obtaining types of cereals more resistant to disease. We have reached astonishingly satisfactory results with the flax plant, having obtained plants both resistant to wilt and rust and apparently in a large way resistant to some of the other more indefinite diseases of the crop. With this crop I know how the resistant stuff has been obtained, and the observations lead me almost to believe in the heritable character of "acquired," or, better, accumulative characteristics, regardless of all that has been said and done in late years to prove the contrary, and regardless of my own early convictions as based upon the doctrines of Weismann.

(1) My first observation is that I can get a resistant type or strain of flax from almost any known variety.

(2) It is much more difficult to induce that resistance in some varieties or strains than in others, but eventually it may be procured in a high degree and in what would seem to be an astonishingly short time, whether we select from mass or from the progeny of a single seed. *The important factor in the process is the constant factor of disease attack.*

(3) In beginning the work I may say that I have never been able to procure what anyone would call a full-fledged wilt-resisting flax plant in the first generation; that is to say, the first generation after selection has never been able to produce anything but what in rough language would be considered scrubs. Sometimes in four or five generations, sometimes in six, eight, or ten the final product brings forth essentially a normal crop on the sickest of soil—*upon a type of*

soil on which originally the parent seed could not have produced perhaps a single plant to an acre.

(4) Then it is evident that the *resisting ability increases from year to year, from generation to generation*, even in a pure, pedigreed strain which came originally from a single non-resisting seed. To illustrate: Knowing of a high-yielding type of flax which gives large yields of seed or the type of straw which is desired when growing on land free from the flax diseases, the writer has found that it is seldom possible to procure any plants if the seed from such non-resisting crop is placed upon the most thoroughly sick soil. The way to get started in this work is to plant the seed of such non-resisting crop upon a soil which is but thinly or poorly infected or infested with the root diseases of flax; or, to plant it on new soil and partially infect the plants with diseases during the growth season.

(5) The author is convinced that to procure resistant flax from non-resistant strains it is necessary to procure seed from sick plants or at least from plants whose roots have been attacked; or at least which were growing in ground which has been infested with the particular root disease concerned.

(6) We have now worked upon the flax proposition long enough to assert without fear of contradiction that a particular strain of flax which has a certain grade of resistance will not lose that resistance if the seed for each following generation is sown upon land in which the disease is abundant and in which the conditions which are favorable to the disease are more severe than those in which the parent plants grow; and the seed from such parentage can be carried to soils which, year by year, furnish more destructive conditions of disease production.

(7) This can, apparently, mean only one of two things: Either that the so-called unit character of resistance was present in an undeveloped form and becomes stronger and stronger from year to year under the conditions of disease, or *that there never was any character there which is entitled to be called a unit character but that it began to develop the first year its parent plants came in contact with the disease, and the protoplasmic nature of the ancestry of the plants which we now have has been such that they have accumulated more and more resisting power from year to year just in the proportion in which they have opportunity to develop that resistance against a constant acting factor of disease which when too powerful acts as an eliminating factor.* The writer does not know but he is inclined to believe that considering the points above

stated and the observations upon which they are based the last feature is the true observation, for it must be remembered that in this work I am dealing not with selections from bulk but selections from year to year from the progeny of a single seed.

(8) Another element which indicates this line of thought quite clearly centers in another method of experimental work. The author has found that many conditions influence the virulence of the diseases. For example, he learned that the presence of barnyard manures or a high nitrogenous content in a fertile soil heightened the abundance or development of the disease and apparently increased its ability to do harm in the same sense as has previously been recorded for potato scab. I therefore started to add barnyard manures to old flax-sick soil to help along the elimination process, planting one or more resistant strains under those conditions. Later I found, as in the case of potato scab, the addition of alkalies, as for example, potash fertilizers, lime fertilizers, wood ashes, kainit, etc., aided the root diseases in their destructive ability. When under the condition of the presence of one of these fungus-invigorating applications to the soil we were able, nevertheless, to select a poorly developed resistant plant, it has been found that such a plant the next year has had resistance to the disease much in excess of that previously noted for that strain or selection.

After I had succeeded in procuring wilt-resistant plants I later found that I had strains of wilt-resistant flax which, though of high worth in resisting wilt and the root diseases, were essentially of no value in resisting rust. Yet, working in those same strains and others which show less wilt resisting powers but high rust resisting powers we have at last been able to turn out flax which neither rust nor wilt can, apparently, affect. For example, this year, one strain has produced approximately 32 bushels of seed per acre on the most wilt sick land, perhaps, in the world, and the sixteenth consecutive crop on the same land and at the same time, surrounded on all sides by other strains of the most non-resisting rust type, strains of flax which were defoliated by rust early in the season. Most of these resistant types of flax which have been in the hands of farmers for four years show that they retain their resisting ability in varying degree. They retain it sufficiently for all of the farmers to be extremely well satisfied, but when the seed is returned to the old ground from which it comes it is found to be resistant in varying degree according to the conditions to which it has been subjected. In some cases it comes back apparently improved in its resistance, in other cases it comes

back essentially spoiled, but in the latter cases we have observed that the difference in resistance is due largely to the matter of physical injury to the seeds themselves under harvest conditions. Perhaps, however, we shall later find that such seed after several years upon land in the absence of the constant disease factor in association with factors of nutrition which are highly favorable to disease production will have lost in resistance. This problem remains to be settled. So far as flax is concerned the feature which is made plain by the experiments is that in order to get the highest quality of resistance developed it is necessary to maintain certain constant factors, one of which is the constant presence of the diseases and another of which is a nutrition factor of constant type. For example, a flax which has had its resistance developed upon a soil highly nitrogenous and highly infected by wilt is not as strong in its resistance to disease when grown upon a soil of light nitrogenous content as a strain of the same breed of flax which has been under the same conditions of disease on a similar soil of poorer nitrogen supply. A strain of resistant flax which has been developed on a soil of high water content in the presence of disease is not as valuable a resistant plant to grow on a dry soil in the presence of disease as a strain of the same origin which has had several years of contest with the diseases on a dry soil of like character. A strain of flax which has had its resistance to wilt developed upon a highly alkaline soil consisting of potash and soda has a high grade of resistance to disease on soils of similar character which is not found in a strain of flax of the same pedigree which has for a number of years been grown upon a similar soil of less alkaline conditions or in soils of low potash and soda content, etc.

In regard to developing resistance in wheat to rust, the writer met with but slight hope of success until he had gained this insight with regard to the action of various diseases which wheat is heir to, including the root and internal seed diseases, and by maintaining constant elimination factors through the introduction of the various disease factors and through the maintenance of soil conditions which are associated with the diseases of the wheat crop, which seem to be capable of essentially destroying the crop, the author believes that he sees the road to the attainment of wheat of real merit in disease resistance. In other words one will not be apt to procure rust resistant wheat by any type of cross-breeding or selection which is conducted in the absence of rust or in the absence of those conditions which develop rust. It is a fact which I clearly demonstrated in Indiana in 1888 and which has been observed by many parties since, that the

presence of highly nitrogenous nutrition factors tended to make wheat non-resistant to rust, or rather tends to high development of rust. It is under such conditions, however, acting as a constant elimination factor and a constant nutrition factor, that breeding and selection, whether it be done by straight selection or by cross-breeding, will be apt to furnish us the plant which we are all looking for; namely, a rust resistant wheat plant for such conditions. The writer believes that if a constant nutrition factor is held against the development of a plant and an intelligent eliminative selection is exercised in association with it, there is great hope of procuring any type of plant which is desired and that while cross-fertilization and the rules of Mendelian philosophy of heredity may greatly aid the work, I feel sure that great gain can be procured and maintained without it, at least in the closely inbred cereals. Further, I believe that without maintaining one or more constant factors of elimination and constant nutrition factors in association therewith there will be slight gain that may be expected from ordinary selection for the improvement of crops and especially cereal crops, whether one is working for the production of drought resistant types, disease resistant types, or simply types of better yielding capacity for particular climatic and soil conditions. It would seem that this is the real explanation of why home grown seed is better than the same pure-bred variety which has had a vacation away from home for a number of years or any other grain of similar breeding which has been brought in from a home of dissimilar conditions. To make clear what I mean, the conditions which one wishes to select against must be severe, must be rigidly maintained, and then one may hope within a comparatively short time to obtain a type of resistance to those conditions which may be carried on to the ordinary farm in such shape as to prove of economic importance. *If these conclusions are correct, there are probably no unit characters which are not fluctuating and there are no fluctuating characters which may not become reasonably "fixed."* Time coupled with the constant factor or factors (*stimulus* or *stimuli* as the case may be) is the factor in all of these matters which is the deciding element. From the side of the practical agriculturist the feature of hope and encouragement is that when once attained in high degree any of these characteristics may be maintained and improved through careful agriculture.