evolving by invention and the pressure of necessity. They will be tested and will endure or be superseded on the same criteria of fitness for survival that have led, through natural selection, to the highly adapted multicellular organisms.

Man as an org is selfish, individualistic and dominated often by the old brain and its emotional attributes. Man as a unit in the epiorganism is altruistic, cooperative, and depends on the functioning of his new brain and its intellectual attributes. But the subordination of the old by the new is not yet sufficient. Human nature is evolving but is doing so less rapidly than is the epiorganism in which it expresses itself. Altruism is not yet generalized to the full group, to the whole human epiorganism, but only to the larger subordinate groups based on race or religion or state. As the units given adherence have grown, so have the conflicts between these units become more massive and devastating; and perhaps still other wars on a still greater scale are to be encountered on the path to world integration. But ultimately this integration must be achieved and conflicts of the present type become impossible.

The new brain, the cerebral cortex, is evolving continuously and greatly under the influence of education, which profits by cumulative social achievement; the world is ever more at our individual doors, and cooperation is being generalized to larger and larger groups; mankind as a whole will become an integrated cooperative unit; and the ultimate future of human society, however dark it may look to the contemporary sociologist or even to the historian, appears in the eyes of the biologist, sighting down the long perspective of organic evolution, as bright with hope.

HOW PLANT BREEDING PROGRAMS COMPLICATE PLANT DISEASE PROBLEMS

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THE present interest in breeding crop plants, together with present means of wide and prompt dissemination of new varieties bids fair to still further complicate disease problems, whether of control, prediction or even of estimation. Given a fairly stable agriculture based on varieties long established in a region, serious fluctuations in the severity of a disease, the kind which are of great economic importance and incidentally of much scientific interest, usually were induced in one of two ways—a marked change in the weather for a longer or shorter period, or the appearance, by hybridization or mutation or by actual introduction, of a new parasite. So generally has this been the case that some pathologists have found an apparent relation between the age of an agriculture and the losses from plant disease. To these students it has seemed that plant disease losses were greater in the regions of newer agriculture.

The list of tragic losses in important economic plants due to introduced insect pests and plant diseases is a long one, too well known to need repetition here. Of the converse process, a serious outbreak of a disease or an insect pest following the introduction of a susceptible variety into the domain of a potentially serious parasite, the history of the potato beetle is perhaps the best known example.

If the historical accounts are correct, the potato beetle acquired its appetite for potato plants very soon after the introduction of the new host. The corn-borer was apparently more deliberate and according to Wardle,[1] "We have historical evidence that the corn-borer thirty years ago was in southern Germany a pest of hemp and hops, and that since its adaptation to corn, it will not seriously attack hemp and hops, even when these plants are grown in close proximity to heavily infested corn fields." Of course, the slightly more than four centuries during which corn had then been cultivated in Germany is really a short time compared with the more than forty centuries which DeCandolle believes hemp had been cultivated, but it is entirely too long to be regarded as a practicable test or quarantine period.

To these two well-recognized methods by which the incidence of losses due to disease and insect pests is strongly influenced, namely, weather changes and introduction, there is now being added, I believe, a third, the work of the plant breeders. It may be worth while to consider future possibilities on the basis of past performance, the only method yet devised for any intelligent appraisal of the future.

On the basis of past performance we may reasonably expect interesting developments in the distribution of disease-producing organisms. As an example of this may be cited the case of the introduction into the northern states of the nematode which causes summer dwarf of strawberries. In the spring of 1930 strawberry plants of the then new and highly regarded variety, Blakemore, were shipped from a region where this type of strawberry dwarf was com-

[1] R. A. Wardle, "Problems of Applied Biology." 1929.

mon[2] to many points outside its known range. Apparently no complete survey has been made since 1931, but the subsequent careful work of Christie[3] leaves little doubt that the disease then introduced into the eastern shore of Maryland is gradually becoming less abundant.

Now that breeding for disease resistance attracts so much attention, we must expect the introduction and rapid dissemination of varieties very resistant to certain diseases. Examples of this are easily recalled. Since they represent a distinct economic gain and disturb no one but the student of plant diseases, they get much attention elsewhere and require little here.

Two closely related results of breeding programs which seem worth special consideration are the introduction on a commercial scale of varieties very susceptible to certain, sometimes new, diseases and the modifying effect of new varieties on parasites long known to be of commercial importance.

At first sight, to speak of the introduction on a commercial scale of varieties very susceptible to certain diseases may seem like a criticism of our breeding programs, but it is not so intended. I struggled with this problem for several years, and became convinced that with our available knowledge, it simply is not possible to so fully test our new varieties as to offer assurance that some of them will not sooner or later prove very susceptible to some disease. This should not be interpreted as condoning any laxity in tests for disease resistance which, of course, should be conducted with all possible completeness and severity, but the number of potential pests is so great and the conditions under which they might become serious so varied that any all-inclusive test would take so long and require culture under so wide a range of environmental conditions as to be wholly impracticable. Just as the real test of a new model of automobile is the road test in the hands of the first twenty to fifty thousand owners, so the real test of a new variety is its culture in the hands of ten to twenty thousand farmers.

As evidence on this point, I would like to quote from the summary given by Stakman, Christensen and Becker[4] of the experience in the spring wheat area of the United States of America during the last 25 years. These writers say, "During the time of observation at least twenty new varieties of wheat were introduced into the spring wheat area and almost every one brought new disease problems with it, or at least changed the old ones." As specific examples they point out that for many years Haynes, Glyndon and Preston were the wheat varieties commonly grown. Stem rust and bunt were then the only really important diseases. When Marquis replaced these varieties over a wide area bunt no longer played any role and stem rust seemed somewhat less serious, but scab, which earlier did not have any significance, suddenly became predominantly important, since the new variety was much more susceptible to this disease.

Somewhat later Hope and H–44, neither of which is in the opinion of these authors a very good variety, were introduced. These are in general more resistant to most of the harmful diseases of spring wheat than any other varieties now available, and are being extensively used for crossing. However, there appears to be a strong linkage in many of these crosses between rust resistance and susceptibility to black chaff to which Hope and H–44 are much more susceptible than any other spring wheats which have been observed up to that time. Just as the wide-spread planting of Marquis made scab of real economic importance, so the wide-spread planting of Hope and H–44 might make black chaff of real economic importance.

In the same paper these authors review the situation regarding barley and state that the disease problem in the case of this crop has changed repeatedly with the introduction and culture of new varieties. In discussing the varieties Velvet and Glabron, which were introduced in 1926, they say "but after these varieties were generally grown for several years it was observed that they were very susceptible to loose smut and scab (p. 62). This latter disease is dangerous because it not only greatly lessens the yield in the case of an epidemic, but also makes the variety useless for feeding to swine because of its toxicity (p. 63).

What may perhaps be regarded as the converse of the relation just described is the effect on parasite populations resulting from the introduction of new host varieties, varieties which by their popularity replace those previously grown and thus make inevitable the development of certain strains of these parasites previously so rare as to be insignificant or even unknown. Here again the work of Stakman and his associates furnishes a good example. Who can fail to connect the increase in form 56 from 0.2 per cent. of the rust population in 1930 to 30 per cent. of that population in 1934 with the coincident great increase in the planting of Ceres wheat, first released in 1926, to which variety stem rust proved so disastrous in 1935?

In considering future possibilities regarding plant diseases it would be folly to exclude what is in some ways the most significant and far-reaching change in a crop plant in our generation, the very general plant-

[2] N. E. Stevens and P. V. Mook, *Jour. Econ. Entomology*, 25: 447–454, 1932.

[3] J. R. Christie, *Jour. Agric. Res.*, 57: 73–80, 1938 (and earlier papers therein cited).

[4] E. C. Stakman, J. J. Christensen and Hanna Becker, *Der Zuchter*, 10: 57–68, 1938.

ing of "hybrid" corn. Unless you live in the corn belt it is difficult to comprehend the speed and extent of the spread of the vogue of hybrid corn. According to Dr. McCall's report to the chief of the Bureau of Plant Industry, 1939, the approximate acreages of hybrid corn were 500,000 in 1935, 1,500,000 in 1936, 3,500,000 in 1937 and 17,000,000 in 1938. In 1939 at least 25,000,000 acres of corn in the corn belt were planted to hybrid seed.[5]

It seems hardly possible that so profound a change can be made without altering the disease relations of the crop. This replacing of open-pollinated corn with hybrid corn fits into the problem we have under consideration in at least three ways. First, in the matter of introducing new varieties very susceptible to certain diseases. If any one imagines that the new varieties, or at least new numbers, of hybrid corn introduced into the corn belt during 1939 and 1940 were so thoroughly tested that their disease relations could be predicted, his knowledge of human nature is even more limited than his knowledge of corn diseases. Nor need we wait for the distant future or for the action of unknown diseases on untested hybrids for evidence of extreme susceptibility. Witness, for example, the havoc worked in Hybrid 960 during 1938 by bacterial wilt and Diplodia stalk rot.

Two of the most experienced entomologists in the Middle West assure me that a somewhat similar condition has been noted with relation to at least one insect. According to these observers, the corn leaf aphid, *Aphis maidis* Fitch, was of relatively minor economic importance for many years prior to the introduction of hybrid corn. During recent years, however, with the introduction of a number of very susceptible hybrids the importance of this insect has greatly increased.

What about the effect of hybrid corn on corn parasites? The change in wheat rust in response to the change in the host population was made possible by the variation continually going on in the stem rust organism itself. Corn parasites vary too, some of them, no doubt, even more actively than in any wheat parasites. That the organism which causes bacterial wilt of corn is made up of a large number of strains, among which there is definite selection on repeated passage through a resistant host, has been proved by McNew[6] and by Lincoln.[7] McNew has further shown that slightly virulent cultures become more virulent after they have grown on certain media.[8]

Just how different the host environment of the wilt organism is in the northeastern sweet-corn-growing states from its environment in the same region ten years ago can be understood only if we review the history of Golden Cross Bantam. This is a single cross made up of two inbred lines, Purdue 39 and Purdue 51. In 1931 seed of this extraordinary hybrid, developed by Glenn M. Smith, was distributed to 61 interested growers in 20 states. Its progress since that time may be best traced from the details in Table 1.

Year	Golden Cross bantam seed produced in pounds	Yellow corn canned		Proportion of all sweet corn hybrids used for canning which were Golden Cross Bantam Per cent.
		Open pollinated Per cent.	Hybrid Per cent.	
1932 ..	2,000	..	..	..
1933 ..	350,000	69	31	..
1934 ..	600,000	57	43	67
1935 ..	1,250,000	38	62	73
1936 ..	1,500,000	27	73	72
1937 ..	1,500,000	21	79	70

These figures were taken from reports of the Raw Products Bureau of the National Canners Association. Accurate figures for subsequent years are not available and may never be since there is a suspicion that Golden Cross Bantam is now being produced and sold under other names.

Not less remarkable than the rapid increase in total acreage is the wide range throughout which Golden Cross Bantam proves to be adapted. It is now in successful large-scale commercial production from Illinois east to and including New York and south through Maryland. Indeed in Maryland it makes up about 40 per cent. of the total crop of sweet corn for canning, although open pollinated Golden Bantam was given up there prior to 1930 because of bacterial wilt. Golden Cross Bantam is now being grown successfully on a commercial scale in Oregon and Eastern Washington and in Western Idaho, though that is not important in the present relation.

The important point here is that from Illinois to the eastern seaboard, throughout practically all the region in which bacterial wilt was so destructive on sweet corn in 1931–1933, its host environment, so far as sweet corn is concerned, has become quite different. Instead of open-pollinated corn, so variable as to become locally adapted and not profitably planted far from the point of production, we have a very uniform single cross dominating sweet corn production over at least a thousand mile belt. Given a parasite which we know to be highly plastic, can any reasonable person assume that the population of this organism to-day can be the same as in 1931?

At some risk of seeming to attempt the dramatic I would like to emphasize the fact that the past decade is the first in the history of agriculture when one could speak of the modification of a corn parasite by a uniform host environment on a scale large enough to

[5] H. A. Wallace, *New Republic,* November 8, 1939.
[6] G. L. McNew, *Phytopath.*, 27: 1161–1170, 1937.
[7] R. E. Lincoln, SCIENCE, 89: 159–160, 1939.
[8] G. L. McNew, *Phytopath.*, 28: 769–787, 1938.

be readily observed, and expect to be taken seriously. I believe it may be literally true that never before in the history of corn culture has a corn parasite been exposed over a wide range to so uniform a host environment. Biologically, including of course its disease relations, we are transforming Indian corn from a freely cross-pollinated crop to a synthetic product.

Elsewhere I have pointed out a relation[9] which may indeed have been all but self-evident, namely, that among comparable crops there is a demonstrable difference as regards disease losses between open-pollinated crops produced from seed and similar self-pollinated crops, disease losses fluctuating more and being in general of greater importance in those plants which are largely self-pollinating.

In a field of open-pollinated corn, there is, I am told, even in the named varieties a wide range in genetic composition and, no doubt, also variation in susceptibility to many diseases. In such a field there is an observable variation in the time of silking and tasseling, and in the time at which plants reach a stage of susceptibility to infection by certain diseases. In contrast to this a field of "hybrid corn" is much more uniform in these respects.

To be sure, the corn now planted consists mostly of double crosses which are somewhat more variable in time of silking, etc., than single crosses. Certain careful growers also plant two crosses in a single field in order that they may still further reduce the hazards due to too great uniformity.

More important in relation to disease and disease-producing organisms is the fact that up until the last few years Indian corn apparently has been able to vary and adjust itself about as rapidly as the disease organisms themselves. Recent researches have shown that in general the common smut of corn, like most smut fungi, is parasitic only in the dicaryon stage, that is, it must cross to parasitize; that it is extremely heterozygous for many characters and consequently unstable; that variation is so common, even in unisexual lines, that from a single monosporidial line more than 150 distinct variants have been isolated; that different combinations of monosporidial lines differ greatly in their degree of pathogenicity and that some of them are so virulent as to kill the host outright.

No one supposes that this ability of the smut fungus or other fungi is recently acquired. It is very much more likely that the process has been going on for many centuries. It is hardly to be doubted that exceedingly virulent lines of smut may occasionally have appeared during these centuries, yet Indian corn survived and has been grown during recent years with a minimum of effective disease control, and apparently much less loss from disease than in the case of wheat.[10]

In corn we are dealing with a native plant, or at least one long cultivated in this area. In many of the places where we now grow corn, our Indian predecessors grew the same plant, which held its own against these same diseases when our ancestors were suffering from the black plague or arguing about the Post-Columbian pandemic of syphilis. All that is now changed and I believe permanently changed. Hybrid corn is here to stay. The increased yield, together with the ease with which seed is produced, makes its future all but certain. Almost equally certain seems to me the probability that we are changing the disease relations of this great crop.

By the wide use of hybrid corn we are depriving this important crop of its power of taking care of itself and by continued crossing and variation, continually adjusting itself to the equally variable parasites which attack it, and have substituted our own choice of parents for each field. In view of our none too brilliant record of success in so testing varieties of other grains as to insure them against loss from disease when planted over a wide acreage, it seems unlikely that we will have much greater success in dealing with corn. It seems much more probable that in spite of the best efforts of the breeders we will see for some years in hybrid corn a disease relation more nearly resembling that in wheat; that is, wider fluctuations in losses with some years very little damage and in others greater damage than has heretofore been observed. Eventually we may see lower average disease losses, but I sincerely believe that our corn breeders will be doing all that can reasonably be expected of them, if during the next ten years they keep the losses from disease in the new varieties, including losses in decay after harvesting, down to the general level of such losses in the old open-pollinated varieties.

OBITUARY

LAWRENCE JOSEPH HENDERSON
1878–1942

LAWRENCE JOSEPH HENDERSON, Abbot and James Lawrence professor of chemistry and chairman of the Society of Fellows in Harvard University, was born in Lynn, Massachusetts, on June 3, 1878. He died suddenly on February 10, 1942.

During the school years in Salem, his home contributed a code of behavior which persisted through life and an awareness of the learning of that day.

[9] N. E. Stevens, SCIENCE, 89: 339–340, 1939.

[10] N. E. Stevens, *Scientific Monthly*, 52: 364–366, 1941.