THE RELATION OF PLANT PATHOLOGY TO HUMAN WELFARE[1]

F. L. Stevens

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In the present era of high cost it is especially fitting that one take account of all expenditures, and weigh carefully the returns. With the present underpaid and poorly equipped condition of many educational and research institutions, and especially in the light of certain criticisms that are made regarding research, I am impelled today to select from the many interesting themes which might be developed regarding plant pathology, and to direct thought to research in the *science* of plant pathology and its related fields, and briefly to indicate the returns therefrom.

Plant pathology is preeminently a practical science, and its prime function is to guide the way to an ever-increasing control over disease.

The magnitude of the annual loss incurred in the United States alone through plant disease in diminution of yield and loss of produce is far greater than it is generally conceived to be. I shall not burden you with statistics, but I do wish to give a few examples, taken from the most reliable estimates that have been made, to indicate the loss. Thus, in the various Plant Disease Survey Reports we find that for the year 1919 losses from plant diseases are given as follows: For the five leading cereals 482,695,000 bushels; for potatoes 86,997,000 bushels; for tomatoes 307,168,000 bushels; for sweet potatoes the loss is put at 58,841,000 bushels, or more than one half the crop. You are all familiar with the diseases mentioned; but you fail to get the world bearing of plant-disease ravages unless you include in your vision such destructive diseases as the coffee rust, affecting in disastrous form a crop of large world value, which in two years destroyed 272,000 acres in Ceylon; the banana wilt, which is reported to have caused abandonment of nearly 20,000 acres of banana plantings in Panama alone and to have rendered useless large railroad lines; the cocoanut palm bud-rot, which kills the growing point of this valuable tree and which is rapidly encircling the world.

Your imagination may fairly picture similar diseases as occurring throughout the world on the whole range of useful plants. Before harvest disease may devastate the crop in the field, and after harvest the inroads proceed in storage. Obviously the loss occasioned by destruction of the product at market is far greater per unit than similar losses in the field.

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Thus a carload of Georgia peaches spoiled by brown-rot in New York means loss of transportation and handling as well as of the original value of the fruit. An annual sum of $30,000,000 is said to be a conservative estimate of the loss in the United States between the field and the consumer, while in 1919 the total loss with fifteen principal food products is estimated at nearly a billion and a half dollars. Even land values are frequently seriously depreciated when the soil is so infested as to preclude the raising of the particularly profitable crop, as, for example, when the tobacco wilt possesses land in the bright tobacco belt, leaving a farm which is comparatively worthless for any other crop, or again, as I have seen, when the wilts of cotton, cowpeas, and melons all occur upon the same field.

As civilization advances, intercourse between regions more or less remote increases and the disease range and prevalence expand. Thus, much as with human and cattle diseases, though to much greater extent, the number of plant diseases known in any community is annually increased by additions from near-by regions or from far-away continents. Presumably the potato late-blight fungus began its journey of conquest in the Andes, and as early as 1845 caused famine in Europe and much loss in many continents. The asparagus rust appeared in New Jersey in 1896 and spread until it reached California in 1901. Many other serious diseases have come to us from abroad, including the sorghum smut, grape anthracnose, cucurbit mildew, carnation and chrysanthemum rust.

Numerous serious diseases have likewise invaded other countries from here, among them the grape black-rot and downy mildew. Of interstate migration interesting cases are afforded by pear blight, from the Hudson valley in 1792 to California in 1895, and by peach yellows from Philadelphia in 1806 to Maine and Illinois in 1886. Among the late continental arrivals are the pine blister rust, which is under such headway that it seems to be impossible of extermination. The value of the susceptible pines is such that the loss may readily reach a hundred million dollars.

The chestnut-bark disease caused a loss of $25,000,000 from 1904 to 1911. Much more serious is the loss to be borne as it invades the great chestnut forests of the Appalachians. Citrus canker, imported from Japan about 1910–11, bids fair to ruin large industries. Potato wart entered Newfoundland in 1909 and was found in Pennsylvania in 1918. It is of interest to note in passing that, were agriculture not taught in the public schools, its presence might yet be unsuspected. Flag smut of wheat was undiscovered in America until May 5, 1919, and is as yet known in but one county in Illinois. This disease is said to cause loss ranging from 10 to 50 percent in Australia.

As increased long-distance communication gives intercontinental transport to disease, so congestion of crop population creates a bridge by which the causal organism may more readily pass from plant to plant or from farm to farm. In these two conditions, facility of transportation and congestion of crop, we find, to a large degree, explanation of the fact that plant diseases are more prevalent now than formerly.

The multiplicity and diversity of plant diseases are especially striking. While the physician has but one species of patient and the veterinarian but a few species, the phytopathologist has to advise regarding many species of plants each of which has, to a great extent, its own large list of diseases. Thus, on the apple alone there are 18 major diseases; on wheat 10; on potatoes 12; while for each crop the number of minor diseases is more than ten times as great.

I have attempted thus briefly to indicate the damage done by plant disease, as a background for a discussion of the part played by plant pathology. The point of importance is not how great is the loss from plant disease, but rather how much influence has the science of plant pathology had in lessening this loss.

Like bacteriology the science is young, dating back barely to the middle of the last century. It was first taught in any American college in 1873 (Illinois), and first as a special subject in 1875 (Harvard). The science has grown until today the American Phytopathological Society enrolls nearly 500 members, the majority of whom are professional plant pathologists, and whereas but one paper appeared in America on the subject in 1861, each month now adds scores of titles and nearly a hundred papers are presented here this week. Large federal and state appropriations sustain its researches.

What is the nature of the return that plant pathology has given? The achievements may be summarized briefly as falling within seven great categories demonstrating the value of: protective applications, sprays and dusts; excision; seed steeps; general sanitation leading to diminution of infective material; breeding for disease resistance; modifications of agricultural practice; quarantine restrictions.

It is unnecessary to discuss these, but I wish to point out that while a modicum of the present benefit doubtless would have obtained from an empirical, rule-of-thumb procedure, the great body of our present knowledge of disease prevention is the direct outcome of truly scientific investigation. It is difficult as you journey from coast to coast today, and see spraying practiced everywhere, to realize that prior to 1885 no spraying was done in the United States. The vast sums spent for copper sulphate, lime-sulphur, etc., and the large factories devoted to making spraying machinery also attest the wonderful growth of this custom. Yet it was not the accident associated with the stealing of wayside grapes that was responsible for the discovery of the efficiency of fungicidal applications; it was the close observation of Millardet followed by his keen analysis and exact experimentation, all of which would probably have failed were it not for the basic knowledge that Millardet had regarding fungi and parasitism. His receptivity of mind was doubtless dependent upon mycological studies of many decades.

Heteroecism of apple and wheat rust and hibernation of many fruit-rot fungi in cankers or mummied fruits, which in the light of science are simple, easily comprehended facts, could without science have had but little more than the force of superstitions. The investigations which have given greatest value to seed steeps have been those that showed the part played by seedling and floral infection. Recommendations of general sanitation would be largely without force were it not that the underlying reasons were made obvious by scientific explanation. Of all the categories mentioned, perhaps the least dependent upon science and the most empirical is that relative to disease resistance, since some of our most valuable resistant varieties have been given to us by farmers, while many of the most susceptible have been eliminated naturally. During recent years, however, knowledge of Mendelism and of biologic specialization has added a very important, truly scientific aspect to this somewhat empirical subject.

Many crops are of such small acreage value that expensive methods of disease prevention permissible with more valuable crops are precluded. In such cases, modification of practice, as change of time of seeding, of crop rotation, of kind of fertilization, of degree of drainage, of age of seed, of depth of plowing, of proper relation of direction of rows to wind and light, has in many cases proved serviceable. The suggestion of such modifications depends upon most intimate knowledge of both crop and parasite, and full life-history studies of the ecology of the organisms are needed. It is obvious that for the establishment of proper quarantine restrictions the taxonomy and morphology of the causal organisms must be known.

It is both impossible and unnecessary to assign any money values to the protection that has been given to American crop plants under the various categories mentioned. A few cases illustrative of efficiency may, however, be mentioned. Cereal seed steeps at a cost of less than three cents an acre effect practically complete elimination of certain smuts. Thus the saving of oats in one state with full utilization of this knowledge would be about 7,000,000 bushels. One spraying for peach curl is stated to prevent 98 percent of the injury with a net profit of more than $400 an acre. Innumerable other examples over the whole range of crop production could be adduced. Perhaps the most striking cases of value of our science occur in connection with quarantine restriction and early extermination of an invading disease. Coffee rust reached Porto Rico in 1902 on stock brought to Porto Rico by a Dutch battleship from the East Indies. It was early recognized by the experts of the Agricultural Experiment Station at Mayaguez, and, though a foothold had been gained, the disease was exterminated. So complete was the elimination that not even a herbarium specimen of the rust can now be found in Porto Rico. If you will visualize the coffee plantations of America paralyzed by this devastating disease, you will give due thanks over your morning coffee to the efficiency of the Porto Rican Station's activity. Another notable eradication was that of the rice smut, properly named *Tilletia horrida* by the Japanese, which was eradicated from South Carolina in 1898 by Dr. A. P. Anderson.

Citrus canker was more tardily recognized, but the expenditure of $1,500,000 by Florida to protect a crop worth $50,000,000 annually and promising to be worth twice that is freely made. The number of cankered trees found in Florida in 1915 was 6,715. In 1919 it was reduced to 4. Perhaps the most significant of cases is that of flag smut of wheat. Picture this as spread over the wheat areas of the United States with an annual loss of nine million bushels to occur over a long period of years. Let us hope that the gravity of the situation is realized and that the appropriation and activities suffice not only to hold it within its present limited range of one county, but actually to eliminate it.

The decay of structural timber, while not, strictly speaking, due to disease, falls within the province of pathology. I can merely hint at the benefits that occur through activities in this field. Certain plant diseases, as the ergots of grain and grasses, have caused serious inroads upon human health and that of cattle. These the science of plant pathology alleviates. I trust that I have given you a partial picture, a mere glimpse here and there, to indicate the manifold, broad, important relations existing between the science of phytopathology and human welfare. Such in general are the field and the achievements, the relations of the science. All the facts that I have presented were doubtless known to many of you; perhaps some were not known to all.

The utility of the science is broadly attested and indeed is unquestioned. Benefits almost inconceivable will result from such extension, or other propaganda, as bring into actual use the knowledge that science has already given us. With the further accumulation of knowledge by the present types of research, other vast benefits will arise regarding each one of the numerous diseases. None is so well studied that further searching will not be rewarded, as is attested by many recent investigations. Accurate knowledge of the flight of sporidia of Gymnosporangium or of ascospores of Venturia, for example, may lead to important modifications of practice. Bud hibernation of the mycelium of a previously much studied group of fungi was but recently discovered.

It is to be observed that the great discovery of the parasitism of the fungi and the founding of bacteriology and the development of its methodology, together with the early foundations laid through the years in histology, mycology, taxonomy, and physiology, have furnished the bases on which plant pathology has made its advance. Aside from these there have been few, if any, great fundamental contributions.

In the earlier days, descriptions, recognition of causes, and trials of obvious prophylactic measures was the usual order. Officials and the public desired immediate recommendations. This type of work as regards the really important diseases has largely been done, and now is the period of more complete, exact study, to lead to new knowledge of fundamental utility. There still remain many problems concerning each disease and many concerning disease in general, but they are for the most part deep and fundamental, not superficial.

Pathology has used cytology to determine relationships and clarify understanding, histology to aid in the interpretation of the morbid, and is constantly dependent upon taxonomy and physiology. Yet, owing to an organization demanding direct application and lacking in opportunity of specialization, and conducive to dissipation of energies over many really distinct fields, these fundamental branches of our science fail to keep abreast of the needs. Taxonomy of the parasites, never satisfactory, in the light of recent discoveries regarding biologic specialization and heredity, is much less so. Few of the many large genera of imperfect fungi, as Phyllosticta, Septoria, Cercospora, have been studied even from a morphological viewpoint. Their cytology, enzymology, life histories, ecology, variability, genetics, are almost unknown. The studies made with a few genera offer suggestions as to what may be done morphologically in such fields, while studies in biologic specialization with the rusts and powdery mildews indicate the need of similar studies with the fungi imperfecti.

The problems of disease resistance and wherein it lies are obviously important. Why, for example, may pear blight proceed at the rate of several centimeters a day down a twig, then suddenly cease to proceed further? Why are some Alternarias parasitic, others not? Questions of inheritance of disease resistance are very complex, and much fundamental work of high value needs to be done. Enzymes and toxins will repay much study. That group of mysterious diseases including the mosaics and peach yellows holds a secret the discovery of which may well be revolutionary in pathology.

Had I time or you patience, scores of problems of equal importance could be mentioned. Many great problems exist, and that they will slowly give way to patient, scholarly attack may with confidence be expected. But since the problems now before us are more intricate than those of the past generation, they demand concentration, larger breadth of equipment, longer periods of sustained research on a given problem, in a word, greater specialization, and this often needs be accompanied by cooperation of widely separated branches of science or of distinct sciences.

The pressure for immediate results, well enough in the era now closing, and which has served its purpose in demonstrating to the world the value of knowledge of pathology, is not the only force that should impel the pathologist to further work. A great part of all research in pathology is now fostered by either federal or state aid, yet Sir A. D. Hall, chief scientific advisor to the Ministry of Agriculture of Great Britain, says that "a government is unfitted by its very nature to conduct fundamental research," and adds that "the scientific man in self-protection . . . is tempted to take a short point of view and not only to do work which will give immediate results but to produce these results very early. Awful examples can be quoted." He says also that "under compulsion of justification there is much danger that the rest of the work is forced to conform to the initial misconception." Without in any way belittling the progress that is being made through the large volume of work of high quality that is done under the present régime, I may add that similar quotations are available from American writings.

Pathology is now become of such large scope that it is beginning to differentiate. It is now demanded that common diseases be diagnosed and treatments recommended, extension work done, surveys made, fungicides and spraying schedules tested, quarantine restrictions enforced, seeds certified as free of diseases, and similar other time-consuming duties attended to. Thus should, and does, arise a division of labor, giving the administration of these important fields to those adapted to them by ability and inclination and leaving the pathologist more nearly free to make his laboratory and field attack upon other problems. This freedom is already reacting favorably upon research in pathology and altering perceptibility the character of the output. But it is clearly apparent that the existing agencies and the motives engendered by pressure of present conditions will not lead to that full, broad, fundamental development that is needed.

More adequate study of the fundamentals clearly means that pathology must come into closer coöperation with all other phases of botany and indeed with other sciences. Such coöperation that mycologists, bacteriologists, physiologists, taxonomists, technicians, organic, physiological, and physical chemists, may together concentrate upon some worthy problem, such, for example, as disease resistance, or the mosaics. This coöperation can perhaps best be brought about by the establishment of an institute, in such manner as to secure not only the desired coöperation but the freedom from time pressure that is needed.

The very success of pathology is in itself a danger in that numerous positions successfully tempt the student to leave his training only partially completed, and, moreover, deplete the ranks of fundamental botany, taking from them those whose abilities and inclinations would otherwise assure their aid in fields kindred to pathology.

A second movement that would tend much to relieve the deficiency would be one that would encourage the individual worker, accentuating a revival of that spirit which impelled Berkeley, the Tulasnes, de Bary, Brefeld, Farlow. It is in the universities and colleges that their successors will largely do their work. Our indebtedness to such isolated workers in the past is clearly recognized, and without their aid in the future we lose much. The necessary limitations of a project system would have precluded the great discoveries of the past, the results of the genius of Darwin and Pasteur, as, indeed, under the project system it is detailed rather than fundamental contributions that are made. I may summarize these points as follows: That, notwithstanding the truly enormous output of high quality and great utility from government institutions, the limitations inherent in their organization are such that certain important deficiencies are apparent. That an institute or institutes for pathology, properly organized, would partially meet these deficiencies. But that, as in the past, we must still look to the isolated students, fired with enthusiasm and willing to devote a life-time to the development of their fields to buttress the structure of pathology and add to its foundations.

Chemistry as a science is strong in numbers and influence because she has maintained her unity. Botany is less a power than she should be because each useful offspring has gone regretfully far from the region of maternal influence. Witness the present separateness of bacteriology, of botany as applied to agriculture, forestry, horticulture, and to an extent to plant pathology. Integration of the various phases of botany rather than further disintegration is to be desired.