hitherto incurable disease is invaded on every side, and that the danger of operation *qua* operation is retreating to a vanishing point.

It is impossible even to enumerate the varied ways in which medicine has cooperated with economics, social legislation and philanthropy, which we sum up briefly as public health. The school house and the scholars, the home of the poor, the colliery, and the factory, the dangerous occupations, the sunless life of the mentally deficient, have benefited, and will benefit still more, by its friendly invasion. And I venture to foretell that, not many years hence, every department of life and work shall be strengthened and purified and brightened by its genial and penetrating influence.

Surely I have said more than enough to justify my contention that we have come into a goodly heritage, and that that heritage is like a lofty and magnificent tableland of knowledge and efficiency. The gaps are being filled; we are no longer isolated, but are working side by side on adjacent areas which are inseparably connected. Every day we gain fresh help from the auxiliary sciences, and we realize more and more the unity and the universality of medicine.

Brethren from foreign lands, we thank you for the treasures, new and old, of observation and experiment, and of a ripe experience, which you have brought to this congress for the common weal.

I venture to affirm that the output of work of the congress week in its twenty-three goodly volumes will astonish civilized countries by its amount and its solid worth.

I welcome you to our dear country, this ancient home of freedom, and I speak not only for the medical men of the British Isles but for our brethren of the overseas dominions, who join with us in our cordial greeting.

May this congress add to the common store of fruitful and useful knowledge; may it increase our good fellowship, our mutual understanding and cooperation, and may it help to break down the barriers of race and country in the onward beneficent march of world medicine.

THOMAS BARLOW

CEREAL CROPPING: SANITATION, A NEW BASIS FOR CROP ROTATION, MANURING, TILLAGE AND SEED SELECTION[1]

Peoples truly rich are those who cultivate cereals on a large scale.—R. Chodat.

FOREWORDS

1. In cereal cropping, air, water and soil fertility (plant foods) are primary matters of crop productivity.

2. The problem of grain deterioration, as now observed by farmers, millers, chemists and agriculturists, the writer thinks, involves the question: "What is the matter with the crop and its product?" rather than: "What is the matter with the soil?"

3. Deteriorated wheat, as seen in depressed yields and low quality, as now quite commonly produced in the great natural wheat-producing regions of this country, is not, primarily, a matter of lost fertility or of modified chemical content of the soil, but is specifically a problem of infectious disease which is superimposed upon the problems of soil and crop management. Crop rotation, for example, is not, primarily, a farm process which is likely to conserve the fertility of the soil, but when properly arranged in a system so that the proper crops follow one another, it is definitely a sanitary measure tending to maximum production.

4. Wheat does not do well in the presence of its own dead bodies, not because of any changes which the wheat plants have made in the content of the soil fertility, nor because of any peculiar poisons (*toxines*) which the crops may be thought to have introduced, but primarily because of infectious diseases which are characteristic of the crop.

5. Proper methods of soil tillage and handling of manures and artificial fertilizers are not merely measures for supplying plant food, but also involve vital features of a sanitary nature.—Bolley.

[1] Outline of an illustrated address given before the students and faculty of the Division of Agriculture, University of Wisconsin, July 20, 1913.

Evidently the writer of the foregoing quotation, who is one of Europe's noted botanists, had in mind the evident biological fact that animal life is dependent upon plant life for sustenance, and the further fact that those countries possessed of tillable acres suitable for the growing of cereals need never suffer for food or forage, for either man or beast—need not be dependent upon other nationalities, in time of either war or of peace. That there is something vital to the thought, let us note for the time being the fearful war that the mountaineers of Montenegro have lately waged, with the hope that they might add to their domain a slightly greater area of level-lying cereal lands in the valley about them.

In late years, there has been a vast amount of talk about cereal crop deterioration, and, for many years, much has been said about "depleted or worn-out soils," and the writers and talkers have lectured and scolded with a vim as strong as though they believed the air supply of the earth were actually proved to be limited (which possibly it is) and that the mineral elements of the soil were rather readily to be lost.

In cereal cropping, this talk and scolding has reached a stage when most of it is mere gossip, inane higher criticism of the common farmer. In this, as in other important matters, there are now quite too many blind leaders of the blind. This is not said with any feeling of criticism, for the writer well understands the thought that where there is smoke there is fire, and further, that through agitation, criticism, contest and investigation lies the road to progress.

There is, however, at present, regarding this matter of soil depletion or cereal crop deterioration, not a little mental rambling and useless counter-criticism among the so-called scientists and agricultural "experts," a tendency to study over the work done by others in similar lines for the apparent purpose of finding and fighting error. The words scientist and expert, in this particular regard, are much overworked. For the benefit of the common farmer, at least that he may escape confusion, we should give these words a rest. It would be less confusing to the general public if no titles were given to those who are trying to instruct on such a difficult phase of nature as how plants and animals live—if they were not led to expect too much, only to meet with repeated evidence of fallibility of supposed agricultural principles.

Within the past twenty-five years great progress has been made by the students of agriculture and of science in general in divorcing the work of life from mere mental philosophizing and in carrying principles of investigation direct to the field of work. In the manufacturing line, this has been done very directly. In the agricultural field we must, without sacrifice of accuracy of detail, do the same thing much more definitely than it has yet been accomplished, if the students of agriculture are to aid the farmer in the way that he must be aided if he is to understand the relation of science to his life work. The introduction of the agricultural college and experiment station idea started out with this thought strongly in mind, though the workers were poorly equipped for the ordeal. These institutions are now becoming powerful, even luxurious in equipment, and it is not at all without the possibility that in our intense desire to be scientific and accurate, and in our worship of the high culture and the accomplishments of the savant, too many of our workers who are paid to investigate agricultural problems may only investigate for their own

enjoyment—may again deal in formulas, and theories, books and philosophies, and thus give out to the working public fine philosophies which may yet leave the worker helplessly in the dark as to what to do.

My belief is that those who undertake to improve agricultural methods, who undertake to furnish the principles which shall direct farm processes, must not be satisfied with the mere study of such principles in the laboratory and the writing of books, which books and pamphlets, because of the nature of things, will be used by laymen for the instruction of the worker. Such men should dictate to themselves the study of actual life conditions of the particular crop which they have under consideration. In directing farm operations so that they shall leave the toiler any remuneration, the scientist must remember that reasoning by analogy is not apt to give him a reputation of infallibility before the farming public.

This is one of the common errors of the present advocates of crop rotation. They give almost every conceivable reason why a crop rotation should be conducted, other than real reasons why the crop grows better under a particular type of crop rotation. For example, one of the chief arguments is that the farmer will have more kinds of crop to sell—will not have all his eggs in one basket. The writer considers such an argument as no reason at all for crop rotation. Indeed, all other types of business are conducted on the opposite basis, namely, a man should do one thing and do it well, and the farmer can not understand the business or professional man who reasons one way for himself and another for the farmer.

It is my belief that the present reason why crop rotation and proper systems of manuring are not properly followed rests not in the innate shiftless or disinterested nature of the American farmer, but because *such* secondary reasons have been given in lieu of real arguments. For example, crop rotation has almost invariably been argued on the basis that it rests the land or improves its fertility, and yet we have been unable to find any proof whatsoever of the truth of such assertion. The writer believes the reason farmers have not followed a persistent and consistent crop rotation is due to the fact that we have not heretofore been given the real reasons which primarily or essentially demand crop rotation in order that healthful, proper yielding plants may be produced on the land.

It is confusing to the farmer and to the layman teacher to read the recriminating criticisms of criticisms, as to the principles of agriculture. Error does not need to be fought, for it falls of its own weight when truth arrives. We are, therefore, I think, to be highly congratulated in this country over the present evident intention of our government and our schools and our investigators to carry the work into the field, whereby the investigator himself becomes more closely the instructor. Middlemen we must have in this work, but let them be as few as possible. I think those investigators of farm problems who have had experience will invariably agree with me that they have encountered much more difficulty in educating the philosophizing institute or extension worker than they ever experienced in getting a farmer of average intelligence to adopt a particular principle under consideration.

The Influence of the Laboratory Chemist.—I am no pessimist as to the value of present scientific methods. They are a matter of development, but there can be little harm done in calling attention to possible improvements in the methods. The laboratory chemist, because of his first

active occupancy of the scientific field and because of the very vital problems with which he deals, whereby each one of the natural fields of science must depend upon him for facts as to the construction of matter, has always had a very strong influence upon the formation of all our theories and principles of agriculture, and I think I may not be open to too strong criticism when I say that we have allowed the laboratory chemist and the untrained middleman or field agriculturist who, in the past, has taken his doctrines largely from the assertions of the chemist, to lead us past many of the problems in cereal cropping.

In this matter of depleted soils and deteriorated cereal crops, it may be admitted that there *are* depleted soils—soils too poor to grow pay crops of any one of the cereals, but they are not, in the belief of the writer, located in any of the present great natural wheat- or cereal-growing regions. The great flat prairie lands of this country which are now producing the so-called deteriorated types, black-pointed, white-bellied, piebald wheat with attendant low yields per acre, are not comparable in the difficulties of maintaining fertility with the denuded water-washed hills of New England, New York, Maryland or Virginia; nor should they be classed with sewage-clogged lands as described by Russel and Hutchinson of the Rothamsted experiments. When I say this for the American natural wheat-producing areas, I may say that I have investigated the problem sufficiently to feel certain that the world-wide problem is comparable to our fertile land problem, is, in fact, in large part the same problem.

Soils may blow away, wash away, or may be sewage-clogged, but these are not, at present, the chief reasons for low yields of wheat, oats and barley in certain naturally very fertile lands of Wisconsin, Iowa, Minnesota, the Dakotas and northwest Canada, or indeed, of the old winter wheat lands of southern Ohio or Indiana.

That you may feel certain of where I stand in the matter, I feel justified in asserting, from my studies and those of various assistants who have been aiding me in my investigations of problems of cereal deterioration, that the chemists are now no more nearly accurate in their diagnosis of the chief wheat troubles in these and other natural wheat-cropping areas than they were a generation ago when the most expert among them insisted that the methods of the chemical laboratory would allow them to determine whether water is fit for drinking or not. They could not then tell whether water would or would not produce disease and death. Neither can the chemists in their laboratories determine the probable productivity of a particular piece of wheat soil. It seems clear, from the investigations of many men, that chemical analysis is no longer the yard-stick for the measure of the productivity of a soil. Rather must we say that *the real measure of the fertility of a soil is the crop which it will produce under a given method of procedure, tillage, drainage, rotation, etc.*

I would remind you that I am not talking against the use of fertility in the growing of crops. I know well the list of essential chemical elements that must be present in a soil in certain reasonable proportions in order that there may be a crop produced. I would remind you, however, that this is not the problem under consideration. The problem under consideration is: Why is it that fertile wheat lands do not produce wheat of reasonably normal quality? Why is it that the yield per acre diminishes rather than increases in spite of present best methods of agriculture?

I again assert, the chemists are not more able to tell by chemical analysis of a wheat

soil whether it will produce normal wheat under normal weather conditions than they were able, twenty-two years ago, to predict whether a certain soil would or would not produce a scabby, gnarled, bin-rotting lot of potatoes. Nor are they any nearer accurate in their diagnosis of the causes of the irregularities of results which are attendant upon present best methods of crop rotation and especially attendant upon the results of the one crop system of wheat growing, than they and others were, but a few years since, when it was continually reiterated that flax wears out or poisons the land against its own growth, that flax is a very "destructive crop on fertility," that flax is very "hard on land," etc., that flax "should have a deep, loose, mellow seed bed and be highly manured if one expects to succeed with it at all." All of which assertions have been abundantly disproved within the past fifteen years.

The chemist and his followers might not have made these errors had the laboratory investigators been willing to go more often into the flax fields and to delve more deeply into the dirt rather than more deeply into the archives of written books to gain ideas as to why the crop was dying.

The Present Status of Cereal Cropping.—That there is a real problem before the agriculturists of the world, especially as affecting the question of maintaining the output of wheat in amount and quality, all must agree. The present approximate annual output of 700,000,000 bushels in its occurrence is somewhat analogous to the varying annual output of gold. It is maintained at these approximate figures, essentially not through increased yields of grain of better quality per acre on old cultivated areas through certain exact methods, but rather through the breaking up or turning over of new areas, in the same wasteful methods. The most alarming feature of the whole condition rests not so much in these facts as in the evident rapid deterioration of the quality of grain which invariably accompanies the first few years of cropping upon the new land areas. Indeed, in some of the newer great wheat-producing regions the most fertile new lands do not produce wheat now either in yield per acre or in quality similar to that which adjoining lands did when first put under wheat culture. This and similar problems the writer believes he is now able to explain. Commonly, the new lands at first, even though of light texture, and of low chemical fertility, are expected and usually do produce grain above the ordinary average as to quality in color, form and milling texture, but, very soon, in spite of the best teachings of our experiment stations and most noted agricultural advisers and experts, even though they themselves attempt the culture, the yield per acre and the quality drops off to such extent that the millers complain bitterly. There is no certainty of quality (grade) occurring, year by year, regardless of the native fertility of the soil whether high or low. The best old cropped soils which the chemist himself will assert are of higher fertility than many of the new unplowed lands, are no more certain of giving success with wheat as to these matters of grade and milling quality than the very poorest. This is but to be expected, for even though there be only fertility of a particular type sufficient for three or four bushels of seed per acre, biologically, there are no reasons why the crop should not, under conditions of health, mature normal seed.

On account of all these conditions of low yield and invariable deficiency in quality, there has gone up a great cry of "depleted" soils, "worn out" land, "bad agriculture," "shiftless methods," etc. This cry follows the plowman regardless of his

improved tools and general farming improvements, regardless of better methods of tillage which we know now obtain on the farm, as against those which our forefathers were able to accomplish, and all regardless of hard work. It is all right for the banker and the lawyer, and even some professors, to berate the farmer for idleness and inefficiency in methods and lack of business, but I say let such men try to raise wheat of high grade under the present general understanding as laid down in books, or by our best agriculturists. In spite of all these directions, the wheat soon becomes soft and shows all of the peculiar characteristics which we find named in the literature of the chemical laboratory, or in the milling tests of wheat as previously indicated, "white-bellied," "piebald," or shrivelled, bleached and blistered, "black-pointed," in fact all of the qualities of deteriorated grain; and the chemist from his laboratory outlook cries out "depleted soils," "lost fertility," "bad physical texture," due to "worn-out humus," "lost nitrogen," "insufficient phosphates," "lime," etc., forgetting, as it were, that almost every field in these matters is a law unto itself and that every one of these fields in the next few years may contradict all these assertions by the growth of splendid crops for reasons no one seems to know. The expert agriculturist and agronomist, who take their cue largely from the chemists, cry out: "Give us intensified agriculture," "Apply phosphates," "Apply lime," "Apply potash," "Grow clover," "Raise corn," "Rotate," all in a confused jumble, and lately the bankers, afraid of their mortgages, have become very busy and tell how to farm and scold rather strongly about lack of business methods on the farm, berate the schools, etc.

These conditions of farm cropping, though not exclusively American, are especially in prominence at present because many of our most noted publicists are becoming, perhaps properly, alarmed. They say our farmers show no ability of maintaining the supply of wheat, the bread grain, a permanent cropping element of old land agriculture, but rather, instead, are reaping lessened yields of poorer quality from larger acreages. They are strongly impressed with the fact that the crop largely tends to disappear as a permanent factor in the agriculture of each community, and this without much apparent regard for the natural fertility of any particular soil. It is thus hardly to be looked upon with surprise that some of our most noted educators and conservationists have become somewhat disturbed and have rather loudly scolded the American farmer for supposed shiftlessness, inefficiency and lack of desire to do his work in a regular way. Some have gone so far as to call the farmer a "soil robber," forgetting that the average farmer, like other people, must live. Such men see the rapid increase of population and the rapid absorption of the public domain and associating these two existing facts with the apparent thought that any intelligent man could raise wheat if only he would follow out present best methods, begin to say harsh things, each according to his own individual make-up, forgetting, or perchance rather not seeing fully, that if he should try hard to learn how best to grow wheat, his mind would become confused by the multiplicity of advisers and the extreme variance of the explanations of why he just as often fails as succeeds when trying to follow out a given method, as, for example, of crop rotation, soil manuring or soil tillage.

The writer having grown up on the farm, and never having allowed himself to get away from the real love of working in

the dirt or soil, has found it rather easy to retain the farmers' viewpoint. In my efforts to solve farm problems through the application of botanical principles, I have invariably commenced at the farm end of the problem, and with an understanding of the farmers' explanation of the trouble. This, perhaps, in part explains why I have never been able to join the ranks of those who scold the American farmer for supposed things left undone. Personally, I have learned that when I have known a principle of plant production and have myself been able to put it into action, I have never had any trouble to get the average farmer to understand that principle and put it into practise. Thus if I were to turn scold, my arraignment would not be against the farmer, but rather against those who have been and are now too cocksure of their scientific principles as worked out in the laboratory, nor should I feel justified in very strongly scolding so-called extension workers. They are much like newspaper writers. They must interest their hearers. They must have something to talk about and can not talk more definitely than the investigators advise. I hope I may not be too pointed in this matter, for these advisers are legion. We have each been guilty of essentially the same fault, namely, the repetition of supposed best principles, perhaps, often urging them more strongly than our personal convictions would actually justify. Half truths are not apt to gain a consistent following among any class of American workers. The simple assertion that crop rotation improves the crop because it saves fertility could not of necessity appeal to the American farmer when he knows well that the next crop which follows may take out even more of the same elements of fertility than the one which has been failing. It is apparent to him that there must in some manner be a fallacy in the argument. Thus it is that the writer explains the fact that there is not at present any consistent following of any definite system of crop rotation on the part of our farmers.

Rather than join the ranks of the scold, I prefer to assert that wheat-growing is a complex problem of life, and that the farmer has never been shown very definitely how to grow wheat. He has never been shown how, with any degree of certainty, to make the crop an annual pay element upon his farm. He has, to be sure, been told to "select good seed," to "practise proper tillage," "apply fertilizers," and crop rotation, etc., but oh! the confusion of all, and the uncertainty of results.

Who is there here who has the temerity to announce that he could follow the advice and win in cash returns with any annual regularity? (I am not here referring to the irregularity of present marketing conditions, but to crop returns, based on supposed fair markets.) What is the system of seed selection? What is the system of soil fertilizing? What is the system of crop rotation? and what is the *why* of each, or at least one *why* of each? Do we know the *whys* of wheat culture as for apple culture? or as for the growing of potatoes, or for the raising of the dairy cow? No, rather are we all confused, advisers and advised, much as we were with regard to potato culture twenty-five years ago.

Too many advisers are yet talking of what they see in the test tube and reporting to the farmer what they have read in books, assuming that they can thus accurately advise without studying the wheat plant in the field.

With any crop, the farmer must be given something definite to do that may give the expected results, at least somewhat more often than not. This information he does

not now have available as to wheat and cereal cropping. That he succeeds as well as he does is proof positive that cereals are sturdy crops. Wheat, for example, is among those crops which man has always had with him since he became reasonably intelligent, and it is probable that only the survival of the fittest, acting under the many interfering unintelligent activities of man, now accounts for the fact that our wheat yields remain as high per acre as they do.

The writer is one of those who believes that *disease, as a factor, has been one of the main agents of elimination, directing the survival of the fittest among cultivated plants as among peoples themselves.* I also believe that when we get our people to understand this problem, the question of sanitation, both our home life and farm cropping work will have a new meaning of very great importance to the public.

The Problem not Alone an American One.—That the problem of deteriorated yields in quality in cereals is not alone an American problem is evident from the literature now appearing in England and other European countries, especially, at present emanating from the Rothamsted farm. By our noted American agriculturists we have been almost led to believe that they had no wheat problems at the Rothamsted farm. All were settled by well-worked-out theories of soil fertilization and crop rotation. Our farmers have been told that if they would do likewise (which is an essential impossibility under present farm conditions) they would have no trouble in boosting our annual yield to 25 or 30 bushels per acre.

When it has been needed to drive our farmers a little harder, we have not hesitated to say to them, "Look at the wheat yields of England, France and Germany," apparently all oblivious of certain great differences in farm conditions existing there which do not exist and which can not exist here for many years to come, and to the further fact that in proportion to their intensified conditions of agriculture, they have the same great proportionate variations in yearly success. Their grains show the same signs of deterioration and they have the same uncertainty that the crop will pay for the labors and money expended. The writer now knows that their troubles are primarily the same as ours. If we are to judge from the reports from the Rothamsted Farm, they have no clearer explanation of the wherefor of the ill effects of continuous cropping than has been given by our own agriculturists who have but largely repeated old explanations.

Theories.—There are many theories as to the causes underlying these irregularities as to cereal-cropping under special methods; especially as to the causes underlying *apparent* soil depletion and wheat deterioration.

1. The Lost Fertility Theory: For ages the farmer has known that proper food prevents starvation, that hay and grain make the fat horse, etc., and from experience knows that what he calls a fertile black, mellow, tillable soil commonly makes strong plants; that farm manures generally tend to give crop increase, though in the case of cereals there is no certainty of this. There may be increased yields, with vital deterioration in quality of seed produced. He has, however, always lent a willing ear to the fertility doctrine and has willingly looked to the chemist to tell him what to do, what to eat, drink, and what to feed his stock. From this vantage point the chemist has from the first had slight trouble in dictating from the laboratory the measure of soil fertility, but I think I am safe in saying that he never has been able to explain why fertile soils and nor-

mal weather conditions do not always measure the crop in yield and seldom in quality. He settles the matter by citing the probability of soil depletion in some measurable available matter of plant food; when this is supplied, if the crop yet fails, he circumlocutes the question by the assertion that there is "bad agriculture," and if the farmer is unconvinced, he and the farmer together are apt to blame the weather or the variety.

2. The Toxine Theory: The farmer, used to the observation that a single crop system sometimes gives sickly-looking plants and failing crops, and that a long rest of the land or a change of crop seems to tend to correct the difficulty, and associating these conditions with the well-known fact that animals, including man, too closely housed and associated with their own kind in large numbers fail to thrive, has always had a dim suspicion that when certain cropping plants are too thick on the land or too continuously returned there, they may tend to poison the ground for their own growth. Certain bacteriologically inclined chemists, or rather, perhaps, bacteriologists with chemical training, unduly impressed with the fact that animals and plants and especially bacteria in a closed space throw off substances toxic to themselves, have of late invented a very plausible poison, toxine or excreta theory by which they reason that plants may poison themselves or introduce into the soil substances poisonous to following crops of the same sort. Some even go so far, apparently, as to believe that almost any soil may contain such organic substances. Thus, for example, Russell and Hutchinson, of Rothamsted, seem to think that a study of cabbage-sick soil might explain barley-sickness; that a study of sewage-logged soil might explain wheat-sickness on arable soils, and Professor Whitney has even tried to explain that grass fails to grow under a tree because of the excreta thrown off by the tree.

3. The Ammonification Theory: Certain of the bacteriologists, over-enthusiastic as to the efficacious power of bacteria to change organic substances into nitrate nitrogen, etc., seem to imagine that cultivated plants could not live in fertile soil without the activity of such organisms. Unable to get away from their chemical training, they attribute almost all of the powers of a soil to produce a crop to the bacterial flora, and have builded about bacterial activities what I think I am correct in naming the "nitrification, ammonification denitrification theory" of crop production, until, when one reads their writings he must, if he assents to their assumptions, believe that a wheat plant could not be expected to thrive in a fertile soil in the absence of such nitrifiers, ammonifiers and denitrifiers in fine adjustment.

4. The Amœboid or Denitrification Theory: Finally, at Rothamsted, England, a subdivision of the latter school of chemical bacteriologists has risen who would grant the essentials of the ammonification theory, but are unable to account for the fact that often in the presence of a highly nitrogenous and otherwise fertile soil there is yet crop failure and irregularity of crop as to quality. They would explain such irregularities or apparent soil deficiencies in crop production by assuming that the proper balance of bacterial flora in the soil has been interfered with. This they explain by the assumption (wholly groundless, I think) that certain amœbæ or other organisms, which, for lack of better name, they call biological factors, eat up the good bacteria, the nitrifiers and ammonifiers and for some reason are unable to digest the denitrifiers, forgetting, apparently, the short life of all of the organisms thus concerned and the evident fact that such a

process could only result in a continuous freeing of fertility. These authors have also apparently made the mistake of studying some other soil than the one which should be studied. All of the phenomena which they mention for sewage-sick soil can in all probability be explained on normal chemical, physical and biological grounds without the necessity of introducing a reversed Metchnikoff theory.

It will be noted that all these theories have a strong chemical bearing, that, in fact, all are trying to explain crop deterioration on the basis of chemical depletion or modification of the soil. They, apparently, all ask: "What is the matter with this soil?" rather than, "What is the matter with the crop?" They do not allow the cropping plant much character of its own as to ability to feed itself when fertility *is* available; and, to my thinking, there is a stumbling block in the way of all these theories. None of them explain immediate crop failure or modification on virgin lands, nor do they explain the production of seed of deteriorated quality on old-worked lands of high available fertility.

As to explaining the types of seed deterioration which the millers have under discussion, I am convinced all fail. Our experiments teach that there are other interfering causes than lack of fertility or of the presence or absence of toxines in the soil, or the presence or absence of a particularly good bacterial flora, or the presence or absence of amœboid organisms which feed upon them. For example, in the case of fruit culture, vegetable gardening and potato culture, I would call attention to the fact that sanitation applied to cropping methods has made a record which should long ago have aroused the chemists and the teachers of agriculture from their apathy with regard to the influence of interfering diseases upon cereal cropping.

I recognize that soil fertility in chemical matter, taken with climate and variety, constitute the primary gage of the crop-producing power of a soil, but I also feel sure that I am pointing out the chief interfering factor which accounts for the irregularities in cereal crop production, namely, *infectious disease resident in the seed and in the soil.* My experience with, observation on, and experiments upon potato-sick soil, flax-sick soil, wheat-sick and oat-sick soils leave me no room to doubt that the various chemical theories of soil deterioration or depletion do not in any way explain the causes of deteriorated grain as seen under the one-cropping system on soils which are characteristically cereal lands. Soil fertility is primary, but a disease problem is superimposed.

Root diseases of cereals, as in the case of potatoes, in all probability account for many of the confusing results which have been obtained under the best and most persistently conducted series of crop rotation, soil fertilization, water culture experiments, etc. These experimenters never used, with certainty, healthy seedlings. When they used manure, they sometimes did and sometimes did not introduce crop-destroying diseases. When they have used artificial fertilizers they sometimes did and sometimes did not apply them to the crops which were particularly subject to disease. So, also, in the past conducting of variety tests of cereal grains, the results are very largely vitiated. In the presence of disease, a resistant variety has been given undue credit for yield and quality, while a non-resistant variety has been unjustly militated against.

My experience with cereal crops with reference to the application of fertilizers, the trial of varieties, experiments in seed selection, seed breeding and seed treatment, and seed purification furnish data which

will allow me to say that I have no fear that all will eventually agree that sanitary considerations with reference to the characteristics of parasitic diseases which are now quite commonly resident in the seed and the soil will yet form the essential basis for the proper management of crops in rotation in series, and the same considerations will largely govern the type of tillage and the manner of handling waste materials on the farm, particularly farm manures. Further, aside from the matter of variety as to food value, the efforts of agriculturists and agronomists with reference to cereal cropping will, in the future, give primary consideration to the selection of seed for sowing purposes, based directly upon its powers of resistance to disease.

The ability of our farmers to do all these things can not be questioned, and when they realize that health among cropping plants is far more important because of the close association of individual plants in the soil, than it is with reference to animal life, they will understand, and will put into action proper sanitary measures for disease control in cereal cropping.

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May 14, 1913

DOCTORATES CONFERRED BY AMERICAN UNIVERSITIES

As shown by the tables published on the following pages, the notable increase in the number of degrees of doctor of philosophy and of science conferred by American universities in 1912 has been followed by a small decrease in 1913. The total number of degrees this year is 461, as compared with 482 last year; the degrees in the natural and exact sciences fell from 273 to 231. Such fluctuations are not, however, significant, being due to natural variations in statistics when the total number of cases is comparatively small. It is not likely that the number of degrees conferred in any future year will fall appreciably below the record for the present year, whereas the average for the first five years covered by these statistics was 233. This represents a doubling of graduate and research

TABLE I

Doctorates Conferred

	Average of 10 Years, 1898–1907	1908	1909	1910	1911	1912	1913	Total for 16 Years, 1898–1913
Columbia	32.2	55	59	44	75	81	66	702
Chicago	35.6	54	38	42	55	57	46	648
Harvard	33.8	42	38	35	42	41	52	588
Yale	31.8	32	44	27	31	31	39	522
Johns Hopkins	30.5	28	27	23	28	32	32	475
Pennsylvania	22.5	32	29	26	29	34	31	406
Cornell	18.1	22	34	35	34	33	35	374
Wisconsin	8.6	17	16	18	23	27	19	206
Clark	8.7	11	9	14	16	6	16	159
New York	6.7	15	13	11	17	10	16	149
Michigan	6.9	4	13	7	6	11	15	125
Boston	4.4	11	13	6	13	8	9	104
California	3.3	4	10	6	6	15	6	80
Princeton	2.6	6	4	8	9	12	13	78
Illinois	.5	5	4	12	11	20	20	77
Bryn Mawr	2.1	4	2	5	5	9	3	49
George Wash.	2.8	3	4	4	5	2	2	48
Virginia	2.8	4	1	4	2	4	4	47
Brown	2.3	2	5	1	4	6	1	42
Catholic	2.0	1	3	3	5	5	3	40
Minnesota	2.4	3	5	1	2	2	3	40
Stanford	1.4	2	3	5	4	4	5	37
Iowa	1.1	2	0	4	3	7	3	30
Nebraska	2.0	2	2	1	0	3	2	30
Mass. Inst.	.3	3	0	3	2	6	1	18
Cincinnati	.3	0	2	2	5	3	2	17
Indiana	.0	3	3	0	2	4	3	15
Ohio	.4	0	2	0	2	5	1	14
Pittsburgh	.1	4	0	2	1	1	5	14
Washington	.7	1	0	0	2	1	3	14
Missouri	.4	3	0	2	2	1	1	13
Vanderbilt	.6	1	1	2	0	1	2	13
Georgetown	1.0	0	0	0	0	0	0	10
Colorado	.5	0	1	0	0	0	1	7
Kansas	.3	0	0	3	1	0	0	7
Syracuse	.2	0	2	1	2	0	0	7
North Carolina	.5	0	1	0	0	0	0	6
Northwestern	.4	0	1	0	1	0	0	6
Tufts	.5	0	0	1	0	0	0	6
Wash. and Lee	.4	1	0	0	0	0	0	5
Lafayette	.3	0	0	0	0	0	0	3
Dartmouth	.1	1	0	0	0	0	0	2
Lehigh	.2	0	0	0	0	0	0	2
Tulane	.1	0	0	0	0	0	1	2
Total	272.4	378	389	358	445	482	461	5,237