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PLANT RESEARCH AND HUMAN WELFARE[1]

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INTRODUCTION

WHEN this country was founded, nineteen people out of every twenty had to spend all their time producing food for themselves and the twentieth person. That was true all over the world. A hundred years ago eight people out of every ten still had to work with the soil, producing food for themselves and the other two people. To-day this proportion is exactly reversed. About two people out of every ten produce the food for the whole ten, or, putting it in another way, one person on the land supports himself, three people in town and contributes to the support of one person overseas.

What is the significance of this fact? Just this: When nineteen people out of twenty have to spend their energy producing food, that leaves only one person to produce everything else. Obviously there won't be much else; certainly there won't be any large-scale industries such as we know to-day. But when only two people out of ten have to produce food, the other eight are released to do a multitude of things. Large-scale factory production becomes possible. All kinds of social services become possible.

In brief, the degree of development of any society depends on the sufficiency of its agricultural resources and the efficiency of its farmers. Only where farmers are efficient and can release other men from the absolute necessity for devoting their time to primary production can the industries, sciences and arts that characterize modern civilization be developed. Our civilization in the United States to-day rests solidly on the achievements of farmers. These achievements

[1] Address before the Kansas Academy of Science, Wichita, Kansas, March 29, 1940.

have made it possible for two people to feed eight others besides themselves.

It has been done through science and engineering skill. Machinery and engineering enabled farmers to produce far more than they used to with the same amount of work. But along with advances in engineering during the past century there have been rapid advances in plant science. The present efficiency of agriculture would not have been possible without a new knowledge of soils and fertilizers and their effects on plants, and a new power to breed more productive plants—plants resistant to disease and other adverse conditions and adapted specifically to machine production. The plant scientist developing a bread wheat that could be grown here on the plains of Kansas contributed as truly to our present civilization as the engineer working out methods for the line production of automobiles.

It may be thought at this point that in spite of all this scientific progress, there are surplus farm products and large numbers of unemployed in the cities. Has science done too good a job? Has it made production too efficient? I think we can answer those questions in this way. If fault there is, it lies not with science but with the use made of science by society. Farmers have not yet produced more of anything than the people of the world actually need—if it were available to them. Every study of standards of living and of consumption shows that people could use more of almost all farm products than they have. The need is not for science to let up in its search for better and more efficient methods of production; the need is to find truly scientific methods of distribution. People with more remunerative employment will purchase more food products. It is desirable now to use the kind of science necessary to build an efficient bridge between production and utilization, rather than to dispense with any of the sciences. The fight against insects, diseases and environmental conditions will probably never be finished. New problems will constantly be arising which will require even better scientific methods for their solution, if we are to maintain the progress made to date.

Why is progress in plant science so important to human welfare? It is the capacity of green plants for manufacturing food—for accumulating energy as food—that makes them the foundation of any system of economy dealing with living things. When plant foods are eaten by human beings and animals, the compounds are broken down in their bodies, energy is made available for growth and movement and parts of the original compounds are again released into the air in the form of carbon dioxide and moisture or returned to the soil. These end products can again be used by plants in building new plant bodies and thus a "wheel of life" is established.

When I think of this "wheel of life," it seems to me that in the past, scientists have neglected the interrelationship between soil and plant, animal and human nutrition. We have been prone to consider the problems of each separately rather than to consider them as segments of the whole.

Early in the development of modern science, specialization became necessary, and to-day we have reached the point where the whole of science is rather minutely departmentalized. Each department has its own language and traditions and pursues its own objectives. By this method, we have accumulated a vast amount of information—for example, regarding the classification, chemical and physical properties and management of soils; and regarding the growth and reproduction of plants and animals. Chemistry, physiology, anatomy, pathology, physics, genetics, bacteriology and other sciences have all contributed to our knowledge of these subjects but each in its separate department without full consideration of a coordination of effort to the broader problems of human welfare.

That method was necessitated by the vastness and complexity of the facts with which science deals, and it is still necessary. But a concept of the unity of nature is no less important than a knowledge of its elements and its complexity, and the time has come when we shall have to devote more attention to a resynthesis of the many facts which are being uncovered but without neglecting the various fields of specialization. Some of the newer methods which seem desirable in attacking our plant and nutritional problems in the future may be pointed out.

To illustrate some specific accomplishments of plant science in their relation to human welfare I shall use illustrations taken from the experiences of the Department of Agriculture and the agricultural experiment stations. To emphasize how the present and the future utilize the past, let it not be overlooked that modern accomplishments are based on fundamental discoveries made by the great scientists of the past.

To-day there are few "plant scientists" in the old original sense. Such a multitude of discoveries have been made that we now have geneticists, pathologists, soil technologists, botanists, horticulturists, agronomists and specialists in other fields. By working together, they have been and are able to apply their various specialties to the solution of important basic and applied problems. But there is still need for more closely coordinating the various specialized efforts in an attack on many of the problems.

Native and Introduced Plants

Now to come to the Department of Agriculture. Long before the establishment of the department, our national leaders recognized the necessity of bringing to this country important plants from the Old World. The earliest governmental recognition of this appears in 1819, but in 1827 a Treasury circular was issued that required "consuls to collect and transmit seeds and plants, with information regarding climate, soil propagation, cultivation, insect pests and uses, and agricultural literature." The Secretary of the Navy asked naval officers to assist in this work. In 1839, there was established by Congressional action an "agricultural depository in the Patent Office," at that time in the State Department. In that office Commissioner Ellsworth (appointed in 1835) was already conducting plant explorations and bringing in importations, which led to the placement of new materials in "every part of the Union." From this beginning the Department of Agriculture developed.

Thus the very first work done by the Department of Agriculture was in connection with plant exploration and introduction. For many years the Division of Plant Exploration and Introduction of the Bureau of Plant Industry has continued to search the four corners of the earth to find new plants that would be of value for various purposes in this country. It is especially fitting to note here that the man who organized and directed this work for several decades received much of his collegiate training in Kansas, Dr. David Fairchild, whom many of you know and who in the last few years has published two extremely interesting books covering many of his foreign expeditions—"Exploring for Plants" and "The World Was My Garden."

Many of the crops grown to-day are taken for granted. Few people realize the part the Department of Agriculture has played in their introduction. Thus Korean Lespedeza, many of the clovers, most of the soybean varieties, Sudan grass, crested wheat grass, crotolaria, Austrian winter peas, navel oranges, dates, sorghums, Egyptian cotton, the tung tree, Ephedra, Oriental chestnuts and many of the hard red winter wheats are only a few of the crops that have been introduced.

Then came another phase of the story. With the improvement of highways, the extension of railroads, the development of refrigeration and cold storage facilities and the opening of new areas of the country, greater concentrations of crops were planted in many areas. Inevitably, diseases and insects, drought, cold injury, alkaline lands and other factors became important in limiting production and causing financial losses.

These conditions necessitated a gradual change in some of the objectives of the Division of Plant Exploration and Introduction, and in the coordination of efforts of investigators trained in the various scientific fields. In many cases in recent years the objective of the plant explorers has been, not primarily to bring back plants from which new crops could be developed but rather to find certain plants that gave promise of being resistant to some of the many diseases or other adverse factors affecting the profitable production of our present crops. With such resistant plants available, specialists could either use them directly or, through breeding, could develop hybrids or derivatives that could be substituted for the less resistant plants. How well this has been done is illustrated in some of the following examples.

Some Recent Accomplishments of Plant Scientists

A few years ago a new mosaic disease threatened the sugarcane industry of Louisiana. The usual methods of controlling plant diseases, such as spraying, crop rotation, etc., were unsuccessful. Production dropped from 250,000 tons of sugar annually to about 50,000 tons. Growers, manufacturers and distributors were faced with ruin and called upon the Department of Agriculture for aid. Our plant explorers visited other countries where sugarcane was grown and were fortunate in finding a wild cane in Java that had the ruggedness to resist this serious disease. Crosses between this wild cane and our domestic varieties resulted in new strains carrying both resistance to the disease and desirable commercial qualities. The sugarcane industry of Louisiana, worth $15,000,000 annually to the growers, was saved, and the working people dependent on cane for employment and thus a living in that area were not thrown out of work.

An excellent parallel to the sugarcane story is the striking success of the plant breeders who have developed strains of sugar beets for the Western States that can grow and produce abundant crops in spite of the curly-top disease. Although not so dramatic perhaps as the last-minute rescue of the sugarcane industry, the development of curly-top resistant beets made it possible to continue the production of the principal cash crop for thousands of farmers in California, Colorado, Idaho, Oregon, Utah, Washington and other states. It is estimated that two thirds of the acreage in these states is now planted to resistant varieties developed cooperatively by the department and state experiment stations.

The use of lettuce has in recent years become general in many homes but few people realize that a few years ago the entire lettuce industry of the Southwest, which produces half of the commercial crop, was threatened by a disease known as brown blight. Growers again turned to the Department of Agriculture and the state experiment stations for assistance. Plant explorers found resistant strains and then the plant breeders and pathologists were able to combine these strains with those grown locally to produce a variety that was disease resistant and commercially desirable. This required only about five years, which is a short time in plant breeding. But just when the growers were feeling that the loss of the industry had been prevented, another disease, powdery mildew, became epidemic and the new brown blight resistant strains were destroyed as readily as the old strains. Fortunately, the scientists had at the same time been accumulating evidence relative to the breeding of lettuce so that in a relatively short time they were able to develop even better strains which were resistant not only to brown blight but to mildew as well. This well illustrates the constant fight necessary in coping with the changing conditions found in plant life, not only to discover ways and methods of producing new crops but to maintain the advances already made.

We hear much about the importance of vitamins in the diet, and children are provided with plenty of orange juice to build up their general health and resistance, especially in winter. The navel orange, which supplies much of this juice, was introduced from Brazil, and it is estimated that it has already been worth more than a billion dollars to orange growers. It is difficult to estimate what this introduction has been worth in improved conditions of health and nutrition of the American people, and the consequent betterment and rise in their standards of living.

Four centuries ago the tomato was unknown to civilized man, yet to-day it is one of the most widely grown and highly esteemed vegetables. The leading commercial variety in use now is the Marglobe, bred by a department worker. When the Marglobe was introduced in 1927 the tomato shipping industry in Florida was faced with ruin because of a combination of two diseases, Fusarium wilt and nailhead rust. The new variety was resistant to these diseases and is now grown practically throughout the eastern half of the United States. The existence of the tomato juice canning industry depends upon Marglobe and other improved varieties.

With reference to the principal crops which supply the great bulk of food for both human beings and animals, such as wheat, barley, corn and potatoes, similar improvements have been made with reference to improved quality and resistance to disease. The planting of hybrid corn, for instance, has increased from about 35,000 acres in 1933 to over 23,000,000 acres in 1939. The development, introduction and use of disease resistant varieties of oats, barley, wheat and other cereals have been big factors in helping to stabilize the production of these crops and in preventing the financial ruin of many families.

Sometimes a pest or disease doesn't make a frontal attack by killing plants outright or making the fruit unusable, but instead, gradually reduces the vigor and yield of the plant. In Georgia, peach trees for many years were affected by a form of eelworms or nematodes that causes swelling on the roots, commonly referred to as root-knot. Plant explorers and research men found the answer to this problem in the form of rootstocks that are resistant to nematodes. At least two resistant rootstocks have been developed. Within the next year or two peach growers in the South and Southwest should be able to buy nursery stock budded on these improved stocks.

Perhaps enough examples have been given to show how plant scientists are able to save crop industries and thus affect the incomes and welfare of large groups of people, and why continued research is necessary. In this constantly changing field, we have to move forward just to hold our ground.

Many of us have seen in our own generation some remarkable changes take place in the food habits of the American people. If we go back another generation or two the change is even more striking. We can recall the time when fresh fruits and vegetables were displayed at the corner grocery only when they were in season. Just try to contrast the grocery stores that we remember as children with those of to-day.

Many factors have played a part in bringing about a change in our diets. The great advances made in refrigerated transportation have certainly played an important role. New methods of growing plants and of feeding livestock, improvements in the manufacture and processing of food products and a desire to keep in step with current trends in our food selection have all helped. Perhaps the strongest urge has been provided by the new knowledge about nutrition, including the vitamins, minerals, trace elements and all the rest.

Changes have taken place in the American diet—desirable changes. But nutritional studies show that very large numbers of people in this country are still far from being well nourished.

This leads to the question, what may we as individuals expect from better diets? We know, of course, that through a proper diet many nutritional diseases may be prevented. We have no proof that diet gives actual immunity to infectious diseases, but there is no doubt about its value in promoting resistance against certain of them. Experiments at Columbia University with rats indicate that diet has a decided effect on length of life. Similar experiments at Johns Hopkins and elsewhere indicate that diet affects vigor and well-being at all ages and that it is possible by diet to postpone the usual signs of senility.

Nutritionists and medical men have proved that there are immense possibilities for building a more robust citizenship in this country through improved nutrition. This means, of course, an attack on both poverty and ignorance. An astonishing number of people can afford good diets but don't know how to get them. Can plant science contribute to the goal of better bodies through better nutrition? My answer is an emphatic "yes."

Some of the means through which this can be and has already been accomplished have been mentioned. New crop plants have been introduced, better varieties developed and cultural and harvesting methods so improved that many commodities, among them dates, figs, broccoli, avocados, pecans, spinach, lemons and almonds, are no longer rarities or beyond the means of the average man but have come to form a definite part of the daily diet. Similarly, the great staple crops such as corn, wheat, oats and potatoes have been so improved in quality, disease resistance and adaptation to production over great areas of variable soil and climate that they are more readily available and better adapted than ever for human food and as feed for domesticated animals.

Research can not stop here, however. There is still a widening and increasing need for further investigations which must deal extensively and intensively with problems of further improvement of quality in plants and with their nutritional values. About a year ago I presented a paper before the American Association for the Advancement of Science at Richmond, Virginia,[2] in which I went into some detail concerning the interrelation of soils and plant, animal and human nutrition. It seemed to me at the time that recent development in the field of nutrition of both plants and animals were opening up vistas of a whole new field of agricultural research.

The point I made then was that the principal objective of many of our plant investigations for some time past has been to adjust soil management practices, change environmental conditions and in many cases modify the above-ground portions of the plant in order to obtain as *large* crop yield as possible; but that recent developments in the science of nutrition suggest that we ought to devote more attention to producing crops of the highest *nutritional* quality for man and animals. I stated: "Obviously here is a case where an interrelationship must be studied—the interrelationship between the physical well-being of man and the factors in the soil that affect the composition and development of plants."

For example, some soils in this country are deficient in certain minerals essential for health while other soils contain large amounts of minerals detrimental to health. It is evident that groups of people, dependent for food upon the plants grown in certain areas or upon animal products produced in such areas, will have food that will be deficient in certain beneficial elements or contain excesses of detrimental ones. There are many examples of the occurrence of physiological diseases of both plants and animals in various areas. Dr. Ouida Davis Abbott of the Florida Agricultural Experiment Station recently told members of the American Institute of Nutrition that farm children in Florida and other regions as well are in danger of severe nutritional anemia if they live on home-grown food from soil that is deficient in iron. She stated that the anemia is not primarily due to hookworm as previously believed; that although hookworm infection affects the degree of anemia, the prevalence of anemia among the rural children is due primarily to diets low in iron. Anemia was discovered in 52 to 96 per cent. of rural children living in regions where the soil was predominately deficient, as shown by the prevalence of "salt sickness" of cattle.

Thorough scientific investigations should be conducted to determine the effects of the various elements upon the growth of plants and of the animals consuming such plants. After surveys and investigations, certain soil areas found undesirable for the production of food might be converted into forests, parks and recreational centers, or used for the production of crops for certain industrial uses as one of the phases of land use adjustment, while other soil areas found deficient in certain desirable food elements might be improved through the addition of the necessary elements in a routine way through fertilizers, irrigation water or sprays applied to the plants. By such means people dependent upon the crops in their own areas would automatically and perhaps unknowingly in most cases have food of high nutritional quality. Such foods shipped into other areas would be equally valuable to consumers everywhere.

NATIONAL ATTACK ON NUTRITION PROBLEM

A national attack on this problem is now being made. Funds have been made available to the government and states for fundamental basic research in relation to agriculture under the Bankhead-Jones Act. Part of these funds were made available for the establishment of special regional laboratories. These laboratories cover such research projects as the breeding and improvement of vegetables; pasture improvement studies; effects of the salinity of irrigation water upon plant growth and the physical composition of the soil; poultry and animal diseases; soybean utilization, etc.

The laboratory most recently established deals with the problem which I have just been discussing. This laboratory in cooperation with various state agricultural experiment stations and other research institutions is located at Cornell University, Ithaca, New

[2] E. C. Auchter, SCIENCE, 89: 421–427, May 12, 1939.

York, and is national in scope. Buildings and greenhouses have been erected and a staff trained in all of these fields has been secured to attack this whole problem of the interrelation of soils and plant, animal and human nutrition. A national advisory council of specialists in the problems of nutrition, geneticists, agronomists, plant physiologists, animal physiologists, horticulturists, soil scientists, botanists, members of the U. S. Public Health Service and medical men, has been formed.

Information regarding some of the soils of the United States with particular reference to their origin, chemical and physical composition, amenability to various treatments and effectiveness in producing plants, is available. An attempt will be made to correlate the composition and nutritional value of foods with soil type, climatic conditions and the practices followed in production. One of the great needs appears to be that of making more comprehensive studies and complete analysis of agricultural soil types and areas and the variety and stage of maturity of crops that grow upon them under known conditions of climate, fertilization and irrigation. Such information would enable us to determine if deficiencies or excesses of certain elements occur in such soils and plants and, if so, to correct the conditions with the ultimate view of improving the health of human beings.

Concurrently, a survey will be made to determine the occurrence of the various elements in fertilizer materials, sprays, dusts and the like and whether such substances may definitely modify the composition of plants and thus make them more nutritious or less nutritious or even toxic to man and animals. Special attention will be given to the physiological effects of the so-called rare or trace elements.

Little is known in detail of the functions of most of the trace elements. Some of them may have subtle and far-reaching effects. Investigations should be made, therefore, of the nature or availability of the compounds occurring in soils and how they are affected by chemical and biological processes in the soil. Studies of the periodicity of the intake or distribution of the elements within the plant and of the differences among species of plants or among strains within a species in their need for mineral elements and their ability to accumulate them should also be made. And in addition, the effects of chemical additions to the soil upon the composition of the plant at various stages of growth will be determined.

Thorough physiological and anatomical studies are to be conducted on plants with reference to the availability, absorption, accumulation and effects upon growth of the various mineral elements—especially the minor elements—including their effect on the elaboration of vitamins, hormones and other compounds. This will involve both field and pot culture studies under carefully controlled conditions, and the further development of special techniques in handling such cultures and of improved analytical methods for the detection of minute quantities of the elements under study.

Consideration should also be given to the digestibility and utilization in the body of the various plant compounds in relation to other factors affecting metabolism and growth. Plants produced in controlled experiments or in various soil areas will be fed to the usual laboratory test animals in order to determine how their rate of development, general health and behavior are affected.

The effects of plants of known composition on human beings will also be determined. There will be wide studies of the adequacy of the various mineral elements and growth substances in the diets of various population groups, especially those dependent upon locally produced food products. It may be found desirable to conduct breeding investigations for the purpose of developing special strains or varieties of plants in relation to nutritional value. Despite the fact that we have certain genetic strains, the manner in which they are grown may modify their nutritional quality.

Although the problems concerned in such investigations are extremely complex and will require considerable time and funds for their solution, still their great importance in our national life justifies and, in fact, demands that such studies be made. We know that raising the level of health of the population is important in all phases of our national life.

This brief outline of the beginning of a comprehensive line of investigation is an example of the many new problems which are constantly arising and which require for their solution the cooperation of the best scientists in many fields. I feel sure that with the cooperation of the agricultural experiment stations, universities, research institutions and private individuals, this and many other problems will be solved.

Conclusion

Now, in conclusion, let me go back for a moment to my original theme at the beginning of this paper. You will remember that I said science was responsible for the development of our modern civilization; and I was not modest about attributing much of this civilization to the development of scientific methods in agriculture. But this is not enough; we can't rest on our oars. Two other things are necessary. First, in order to *maintain* what we have, we must keep constantly on the job with the kind of research I mentioned in connection with plant diseases. You might call this *defensive* research; it is the method by which we defend ourselves against a host of hostile forces. Second, we have to have another even more far-reaching kind of research that looks to the future. You might call this *aggressive* research. Certainly we are not entirely satisfied with the civilization we have to-day. We want to go forward, to build a still better civilization. And as science made our present civilization possible, I believe it will also make possible the better civilization of the future if we keep on with *aggressive* research in all the sciences, natural and social.

OBITUARY

WAYNE J. ATWELL

IN the untimely death of Dr. Wayne J. Atwell on March 27, the University of Buffalo has lost one of its most valued teachers and administrators, and the world of science has been deprived of one of its ablest and most energetic investigators.

Wayne J. Atwell was born in Fairfield, Nebraska, in 1889. After graduation from Nebraska Wesleyan University in 1911, he entered the University of Michigan as a medical student. Becoming interested in the morphological sciences, he discontinued the study of medicine, and under the inspiration and guidance of the late Dr. G. Carl Huber, began his career as a teacher and investigator. He was granted the degrees of A.M. and Ph.D. by the University of Michigan in 1915 and 1917, and served as assistant or instructor in the anatomy department of that institution until he was appointed professor and head of the department of anatomy of the University of Buffalo in 1918. In the latter institution, after several years spent in building up his department and its staff, he was able to continue his medical studies on a part-time basis, and was awarded the degree of doctor of medicine in 1934.

Dr. Atwell's first contribution to the literature of science was a paper on the relation of the notochord to the hypophysis, published in the *Anatomical Record* in 1915. In the same issue of the *Record* he published a shorter article describing the conversion of a photograph into a line drawing.

During his graduate study under Dr. Huber he acquired skill in a variety of techniques and procedures which were of value in his later investigations, the results of which were usually elucidated in his papers by excellent drawings of sections, models or reconstructions, or by skilled photography. His thorough and critical study of the development of the hypophysis of the rabbit, on which he prepared his doctor's dissertation, fixed his interest in the morphology and function of that organ and determined the trend of his later research. The morphology of the organ, sometimes with particular reference to its pars tuberalis, was treated in a series of papers on its embryology in the tailed amphibia, in man, and in the chick; his last completed scientific paper, which appeared during the month of his death, dealt with the morphology of the hypophysis in several species of toads. These various embryological and anatomical studies were supplemented by an investigation of the histology of the pars tuberalis, and a study of the Golgi apparatus in the cells of the anterior lobe.

The numerous morphological studies mentioned above naturally led to an interest in the functions of the several parts of the hypophysis and stimulated the experimental work which constitutes much of Dr. Atwell's later contribution to our knowledge of the organ. Beginning in 1919 with a short report in SCIENCE, he published a number of papers dealing with the relation of the pituitary to pigmentary changes in the amphibia, and the nature of the pigmentary responses in these animals; his latest investigation in this field was to have been presented before the American Association of Anatomists at its April meetings in Chicago. He also investigated by experimental methods the thyreotropic and adrenotropic hormones of the anterior lobe, as well as certain pituitary-adrenal-gonad relationships; and he attempted through the use of extracts prepared from it, to determine the functional role of the pars tuberalis. He developed methods of transplantation of the pituitary anlage in amphibia and utilized hypophysectomy with and without such transplantation in several of his more recent studies. All in all, he played a highly important part in the establishment of our present concepts of pituitary structure and function.

In addition to his many papers on the hypophysis, Dr. Atwell reported (or aided his students to report) certain of the more rare anatomical anomalies encountered in the dissecting room. His outstanding work outside the field of his pituitary investigations, however, is his painstaking study of an early human embryo, published in the Carnegie Contributions to Embryology in 1930. This embryo has since been mentioned and figured in text-books of embryology as the Atwell embryo.

At various times Dr. Atwell served on the staff of *Biological Abstracts, Endocrinology* and *The American Journal of Anatomy.* He also served as president of the Western New York Branch of the Society for Experimental Biology and Medicine and as a mem-