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THE RELATION OF SCIENTIFIC RESEARCH TO AGRICULTURAL PROGRESS[1]

By Dr. A. F. WOODS
DIRECTOR OF SCIENTIFIC WORK, U. S DEPARTMENT OF AGRICULTURE

A HALF century of service in finding and proclaiming facts underlying agriculture is a record worthy of the highest commendation. The world as well as the nation and the state have felt the helpful influence of the work of this station. It has been in the past and is to-day an active, helpful unit in the great federation of workers, ever seeking by new and improved techniques and clearer vision to give man surer control of those factors of his environment that make up what we call agriculture. It is a wide field, involving almost the whole range of our physical and biological environment, including man himself.

We may well pause at this half-century mark and ask how much we have gained through the development of natural sciences bearing on agriculture.

A half century ago it looked to the best scientific minds as if increase in population would overtake and pass our power to produce food to meet the need. The zero hour was set at about 1933. The day is here. Populations have increased at about the ratio figured, but we can feed them all to-day more easily and cheaply than we could at any time in the past. There is less famine, less suffering, less hard work, and more leisure than ever before. The reason is that we have more accurate knowledge of the factors that must be controlled and we control them better than ever before in the history of man. This knowledge we have gained step by step through carefully planned experiments and the development of what we call scientific method, which is simply a method of trial by which we are able to measure and control each step or process and thus find the true relation of each factor under each set of controlled conditions.

[1] Address at the celebration of the fiftieth anniversary of the founding of the New Jersey Agricultural Experiment Station, October 8, 1930.

From such observations modes of action can be determined and controlled and thus we formulate what we call our physical, chemical and biological laws. These laws operate with considerable certainty within the range of our observation.

It is this method that has given birth to what we call modern science. Some of it has grown out of a study of plants and animals under domestication, as Darwin's formulation of his theory of natural selection, Mendel's studies of inheritance of unit characters and his formulation of the manner of inheritance of such characters now known as Mendel's laws. These two deductions have given us greatly increased power to modify species and to make new ones embodying new unit characters and consequent qualities and to have these fixed true as in nature. But while nature may take a thousand years to produce a new species we can do it in a very few years or in some cases in a few weeks.

The plant and animal have become as plastic in our hands as the molecule and atom have in the hands of the modern chemist and physicist. A new world of interest and power has opened up to us that we have scarcely yet begun to explore.

This increased knowledge and power has been acquired not by spinning logical theories but by observing and testing and basing our hypotheses and theories on observed and tested facts.

In this work the agricultural experiment stations have been busily engaged for over half a century. They have as a result built up a body of experimental evidence in relation to almost every aspect of agriculture and country life that is gradually changing the whole aspect of agriculture in enlightened countries from a haphazard, rule of thumb work for peasants to a dignified, interesting and successful group of industries, able to hold their own, and to render efficient service in civilized society.

This may sound strange to ears that have for so long listened to the wail of the downtrodden farmer. It is necessary to use an intellectual grid screen to eliminate this static in order to get the true symphony of the new agriculture born of the scientific spirit.

The Soil

The soil to-day is not just dirt but a universe of life and activity, billions of organisms from the microphages—invisible under the highest powers of the microscope, bacteria, protozoa, microscopic algae, molds, fungi, and a multitude of higher forms, all engaged in breaking down and building up processes that all together make soil.

The factors that favor the fertility-producing and conserving processes are being discovered, as well as those that work in the opposite direction. We are learning to promote the helpful activities and to suppress the harmful activities. The chemists have discovered that out of all these activities there are developed certain colloidal substances that have much to do with what we call soil type. These colloids, with the organic matter which in the past we have lumped under the term humus, have a controlling relation to crop-producing power.

These and other factors are all considered in our soil surveys and land classification as a basis for a more highly developed and permanent agriculture and in reclamation procedures.

Then, too, we are beginning to realize the tremendous losses of fertility and waste of soil from slow as well as rapid erosion and we are beginning to take steps to prevent these losses as far as possible.

The New Jersey station is one of the foremost leaders in this soil research.

The Plant

The old botany was largely the naturalists' interest in the orders, species and varieties of plants as they occurred in nature. Down to the time this station was founded plants as well as animals were everywhere considered as fixed entities that might vary a little under changing conditions of environment, but always remained within the fixed bounds in which they were created.

As I have already suggested, this viewpoint has been changed as the result of research. We still have the families and species, but they are more or less plastic in the hands of the geneticist. We have learned that the hereditary characters are carried in the chromosomes of the germ plasm nucleus and that these chromosomes are made up of smaller bodies not much larger or more complex than some of our chemical molecules. We have learned that these have a definite relation to each other in the chromosome and that this definite relation controls the form and activity of the individual resulting from the egg cell.

Regroupings can be produced by crossing or hybridization or can be brought about by other means, such as certain forms of radiation, thus producing mutations in enormous numbers from which selections may be made. Much of this work has been done by our stations.

It is fundamental research that is giving us increasing control of these processes that nature uses in her evolutionary development. The time factor has been greatly decreased.

New corns, new wheats, new sugar canes, new cottons, new varieties of grasses and clovers, new fruits, new flowers, have been produced by the thousands by controlled breeding. We now search the earth for plants having unit characters that we may need as well as already developed varieties. Cold and drouth-resistant wheats and alfalfas, wilt-resistant cottons, cowpeas, flax, melons, sugar canes resistant to virus diseases, potatoes resistant to these and other diseases have been produced. The plant breeders are constantly improving, developing and adjusting crop plants to various limiting factors and quality requirements.

We have long realized how fundamentally important plant life is to the existence of animal life. We know that plants are able to combine carbon, hydrogen, nitrogen into forms available to animals. They do this with energy absorbed from sunlight. We have known a little of these products of photosynthesis, starch, sugar cellulose, pectin, organic acids, and a host of other organic products about which we know very little.

Recently our station investigators have opened up a new field in the so-called vitamins that are found to have extremely important relations to animal development. They control growth and reproduction, resistance to many diseases in animals and man. Almost every year our investigators are bringing new aspects of these important matters to light.

Then there are other light relations that have only recently been discovered, *viz.,* the relation of periodicity of light exposure to the development of plants. In nature this is regulated by the seasons and by day and night. We have developed some control of resting periods and growth, but flowering and fruiting in the majority of cases could not be controlled until one of our scientists discovered that by changing the length of exposure to light and darkness he could change the flowering and fruiting period. This is proving to be a most helpful control in bringing plants to bloom at a desired period, either for commercial or research purposes. It is a new field in which there is research yet to be done.

There are many chemical processes carried on by plants that yield extremely valuable food and medicinal products that have been produced with difficulty or not at all by the biochemist in his laboratory. In some cases it would be extremely valuable to be able to produce these more cheaply and rapidly than can be done by plants.

Among these is an organic poison known as rotenon, produced by a number of tropical shrubs and extremely valuable as an insecticide because it is not poisonous to the warm-blooded animals and is extremely poisonous to insects both as a contact and stomach poison. If we could find out how this is synthesized in the plant it might give us a clue to chemical synthesis in the laboratory and this in turn might lead to efficient commercial production.

The same is true of nicotine, another valuable insecticide, but more or less poisonous to higher animals. The supply available from tobacco waste is not sufficient to meet the requirements. A synthetic material very closely related but not quite so effective as nicotine has been developed but we hope to improve on it.

Bacteria of certain types are able to fix atmospheric nitrogen and make it available to higher plants. The process is rather slow but the method is far more efficient than anything we yet know in our laboratories, with all the improvements we have made in the past few years. How does the bacterial cell accomplish this fixation? If we can find out perhaps it may suggest further improvements in our laboratory and commercial processes.

These examples will indicate the great importance of research in these fields.

Our plants, like animals, are subject to disease. Disturbances in nutrition, attacks by bacteria and fungi, and the filterable viruses cause hundreds of millions of loss every year.

A new science, phytopathology, has been developed in our efforts to cope with these diseases. The first progress along control lines was in the use of fungicides. The U. S. Department of Agriculture and the experiment stations have led the world in this development. The same is true in regard to insect pests. The warfare grows more intense every year. The increasing ease of communication between hitherto isolated regions has made it possible for many fungous and insect parasites to move to cultivated plants related to their wild hosts. With the improved food conditions they multiply enormously and become major pests. Plant lice, leaf-hoppers, grasshoppers, crickets, potato beetles, are all well-known examples of those that have moved from wild to cultivated plants. The cotton boll weevil, the pink boll worm, the Japanese and Asiatic beetles, the corn borers, the Mediterranean fruit fly, and others too numerous to mention, are some that have been brought in. Here, free from their enemies, they have become a serious menace to our agriculture. Most of them can not be eradicated, so the best that we can do is to import their enemies when those enemies are not likely to be injurious, and also to develop other means of suppression and control.

This involves a careful, detailed study of the life and habits of all these pests, but it is the only hope of successfully keeping them in check in highly developed agricultural regions.

The same is true of plant parasites, rusts, smuts, mildews, bacteria, and hosts of others. One little fungous parasite is rapidly killing off our chestnut forests. No adequate means of control has been found. A destructive elm disease is knocking at our doors, and there are many others known and unknown that must be kept out. But I must not linger in this fascinating field, though I have barely touched it.

ANIMAL INDUSTRY

Another phase of our agriculture of outstanding importance is animal husbandry. It transforms the lower-grade food products into those of higher value —milk, butter, meat and by-products. The progress that has been made in animal breeding is well known to all.

In recent years, however, much greater efficiency has developed in breeding for efficiency of performance in a desired line rather than for certain unimportant characters. Our stations and the U. S. Department of Agriculture have led in developing these methods through more careful application of the laws of genetics.

In the field of animal nutrition great advances have been made—the balanced ration, the relation of the quality of the ration to the quality of the product, the discovery of vitamins, all grew out of this work, and it is only in its beginning.

Very great contributions have been made in the study and control of animal diseases. Perhaps the outstanding contribution was the discovery by workers in the Bureau of Animal Industry of the Department of Agriculture that a microorganism found in the blood of cattle suffering with a disease known as Texas fever was the cause of the disease and that the cattle tick is the means whereby this disease is transmitted. This was the first demonstration that a microbial disease could be transmitted through the intermediate host or carrier.

This discovery ranks among the great achievements of medical science. It led to the discovery that other diseases, like malaria and yellow fever, are carried by mosquitoes, typhus fever by lice and other insects, African sleeping sickness by a fly, Rocky Mountain fever by a tick, etc.

This knowledge gave the key to the development of methods of eradication and control.

As stated in the Yearbook of the U. S. Department of Agriculture, 1930, studies begun in the same bureau in 1885 showed that resistance to disease could be produced by injection of killed cultures of the organism causing it. This led to the development of the method of vaccination against typhoid fever and other bacterial diseases.

Many other fundamental researches on animal diseases have been made by the department and the stations that have been of inestimable value not only to agriculture but also in the treatment of the diseases of man.

In the field of animal parasites an outstanding example was the discovery by a department scientist of a new species of hookworm that attacked human beings in our Southern states and many tropical countries. Effective remedies were also discovered by the department.

Through the efforts of the International Health Board of the Rockefeller Foundation the methods have been used in many millions of cases in all parts of the world. Bovine tuberculosis, hog cholera, and a host of other diseases have been investigated and important progress made in controlling them. No branch of the work of these institutions has rendered more important service to agriculture and to humanity or offers greater promise of future service.

It is a mistake to say that the work done by the Department of Agriculture and the experiment stations is for the benefit only of a class or in the interest of pigs and corn. It is of direct service to every man, woman and child in America, and I think I may safely say in the world, as scientific discovery knows no bounds. It belongs to all the world.

Recent legislation has enabled the department and the stations to study more deeply in the economic and social fields. While great contributions have been made individually in these fields by the department and the experiment stations very little thoroughgoing, systematic study has been carried out. Much, however, is now being organized and we may look in the future for a more scientific basis for our economic and sociological planning.

All the great undertakings, including industries and business, rest upon carefully ascertained facts. They have their scientific agencies to get the facts and to search for still more facts and means of applying them to advantage.

Agriculture spends through the Federal Government and the experiment stations close to $30,000,000 a year for a $60,000,000,000 group of industries, with an annual turnover of $10,000,000,000. This investment has made American agriculture, with all its shortcomings, the best in the world. Other industries spend nearly $200,000,000 for research and the amount is increasing yearly. It is the way of progress and safety and offers most for the present and future welfare of man.