SCIENCE AND AGRICULTURAL EXPERIMENT.

By J. A. STEWART.

For the farmer, sciences are being ransacked; and labor and learning are laying their stores at his feet. The application of science to the needs and purposes of agricultural workers has naturally had a retroactive effect. Science, in turn, has been enriched and enlarged by the results of experimental research.

To what extent this has been done is best realized from the records of the work of the experts in scientific inquiry, as represented in the National Department of Agriculture at Washington, and in the network of agricultural experiment stations which extends to all parts of the country. These stations, which have enjoyed such remarkable expansion and usefulness in the last decade, are centers of scientific thought and demonstration. Their investigations, the results of which have been scattered broadcast in printed form, have materially affected farm practice in this country. And it is a significant fact that the more scientific they are, the more they are relied upon by progressive farmers for advice and assistance.

It is an acknowledged fact that the agricultural experiment stations and the agricultural colleges with which they are usually connected have produced an agricultural science for America. They have happily made their contributions to human knowledge a matter of popular comprehension. They have trained special investigators who have made valuable discoveries as a result of their research. The extent of the United States, the variety of its climate and topography, have rendered very wide its range of vegetable production and its opportunity for building up an agricultural science. In the great agricultural changes which have taken place during the last quarter century it must be conceded that the agricultural experiment stations have played not only a most important part by their application of science to local needs in the agricultural arts, but also in their definite and valuable contributions to science itself.

Scientific investigation and experimental work in agriculture, it is pertinent to note, began with scientific investigation in a few lines, carried on chiefly by college professors as supplementary to their regular duties of instruction. When the first station was equipped at Albany by the New York State Agricultural Society, its work related chiefly to the analyses of soils and manures. Its chief equipment was a chemical laboratory and its labors were almost entirely in the interests of chemistry. When the stations were established in connection with the land-grant colleges in 1862, each was given a definite portion of the college farm for its exclusive use. These station farms are generally divided into limited areas on which plant experiments are conducted; horticultural plantations, including vegetables and small bush and orchard fruits; fields devoted to experiments in growing crops on a relatively large scale; fields in which forage crops are grown for use in experiments with silos, the feeding of animals, dairying, etc., and pastures or woodlands. These farms are provided with more or less elaborate systems of drainage, and in many of the States west of the Mississippi River have irrigation ditches with the accompanying water rights.

Each station consists usually of one or two main buildings which contain the executive offices, the chemical, botanical, bacteriological and other laboratories, museums and libraries. In respect to other provisions there is a wide variety. Barns which are utilized for housing live stock, storing grain and forage crops, or are fitted up with special reference to feeding experiments; piggeries, and poultry houses are quite common. At a number of stations there are vegetation houses and buildings set apart for experimental work in dairying. Glass houses in which insects may be bred and their life history studied are unique features at some stations, originating at Cornell University Station. In a similar way provision is now made at a number of stations for the culture and treatment of fungus and other diseases of plants.

Naturally the stations are well equipped with scientific apparatus for work in chemistry, botany, bacteriology and entomology. The work of the stations has led to the rapid increase of scientific apparatus for studies in vegetable physiology and pathology, and agricultural physics, and the invention by station workers of apparatus for special purposes.

Two of these notable inventions are shown in our pictures. The origination of the Babcock test is the most widely known result of the Wisconsin station's work. This is a method for the rapid determination of the percentage of fat in milk. It was devised by the chief chemist, Dr. S. M. Babcock, and the first account of it appeared in July, 1890. Since then the station has issued over 60,000 copies of bulletins and reports in which it is described.

The apparatus for determining the effective size of soil grains consists of a water receptacle; an aspirator bell; an air tube, leading from the bell to the air chamber, and a soil tube provided with a tight cap at one end and a cap with wire gauze at the other. The air-meter is a clock gear, as shown in the illustration. The pressure gage is represented at the left, consisting of a pressure tube connected with the large water receptacle, used to avoid reading the gage at both ends. The pressure is developed by a weight. This unique apparatus, it is held, fully fills the long-felt want for a method of soil examination which shall give definite data regarding the effective surface of a unit volume of soil, both for the holding of soil moisture and for the solution of plant food; and to show whether or not the grouping of soil grains in a virgin soil is fundamentally different from what it is in the same soil after it has been long under cultivation.

Large collections of specimens have been made in some instances by the experiment stations.

It is a fact not to be gainsaid that the problems of agriculture furnish adequate opportunity for the exercise of the most thorough scientific attainments and the highest ability to penetrate the mysteries of nature. The work of compilation undertaken by the station experts preliminary to entering upon distinctively scientific research was necessary in order to supply both farmers and experimenters with the essential data, and to lay the substructure for the later scientific work. The work, as has been stated, brought to the front groups of trained scientific experts whose

investigations have involved many original discoveries in physics, chemistry, botany, zoology, entomology, geology, meteorology, agronomy (plant production), horticulture, forestry, physiology (of man and domestic animals), zootechny (animal industry), veterinary science, agrotechny (agricultural technology), and rural engineering.

The stations are at present conducting a wide range of scientific research in the laboratory and plant house, and an equally large amount of practical experimenting in the field, the orchard, stable and dairy. Among the most important scientific investigations have been those along the line of economic entomology. This has produced additions to our knowledge of many beneficial and injurious insects, including in many cases the completion of their life histories; studies in the breeding of insects, especially as a means of their investigation; the discovery or invention of methods and appliances for the repression of injurious insects, and for the study of insects. Among the insects on which the station entomologists have made extensive studies resulting in the development of effective methods for their repression are the codling moth, plum curculio, scale insects, chinch bug, Rocky Mountain locust, woolly aphis, cotton worm, boll weevil, forest insects, and insects affecting stored grain. Systematic studies have also been made in other lines of zoology, especially of such injurious mammals as gophers and rabbits, and of useful and injurious birds. There have also been contributions to the life history and culture of oysters and the life history of nematodes.

At Cornell Station, N. Y., a root cage has been devised for the observation of subterranean insects. At the Ohio insectary, shown in our illustrations, there is a collection of about 4,000 insects, about one-half of which have been reared and studied at the station.

In agronomy, the introduction of new varieties of crops adapted to special regions or particular economic purposes and the improvement of species by selection and by plant breeding, have been the special features of scientific work. The most notably successful of introduced plants has been the Australian saltbush (*Atriplex semibaccata*). Its value has been demonstrated on the arid and semi-arid lands of the West in an economic way by rendering available for grazing purposes thousands of acres of land hitherto practically worthless. Its success led to the scientific discovery that all upland soils in arid climates contain from 2,000 to 4,000 pounds of alkali per acre without giving any visible indication of it. The culture of cotton has been the subject of scientific investigations in the South, where years of continuous cotton production have impoverished the soil—a study which has led to important experiments in soil inoculation and the value of certain soil micro-organisms for the successful growth of leguminous plants.

Exceedingly important contributions to science have been made in the physiological studies in nutrition in which 14 stations have engaged and in which very little experimental work had previously been done either in this country or in Europe. From the scientific standpoint, the respiration calorimeter, devised at the Connecticut station is most important, as it has revolutionized the means by which the study of the application of the laws of conservation of matter and energy in the human body can be carried out to a completeness never before attained. This apparatus, it is pleasant for American scientists to note, has obtained recognition abroad, the Prussian government having ordered a similar apparatus for the Institute of Animal Physiology at Bonn, under Prof. Hagemann; and one has also been constructed for a similar institute at Budapest under Prof. Tangl.

In agrotechny, twenty-nine stations (including Illinois and Wisconsin, whose fine buildings we show), are making chemical and bacteriological studies of milk and dairy products exceedingly valuable, both from the standpoint of pure science and practical utility. For instance, the result of extended feeding experiments has shown that a safe standard ration for a normal dairy cow, producing 1.2 pounds of butter fat daily and weighing approximately 1,000 pounds, was 2.06 pounds protein, 12.5 pounds carbohydrates, and 0.89 pound fat per day. A method for counting and measuring fat globules in milk and an apparatus for determining the viscosity of milk have been devised at the New York station. The investigations into the extent and character of milk infection with micro-organisms; pasteurization; the use of pure or of definite cultures in butter-making and cheese-making; the nature of the changes in the ripening of cheese and the kinds of organisms causing them have contributed important additions to bacteriological information. The working of these problems has led to the discovery of a ferment in milk hitherto unknown, which is believed to play a very important part in cheese ripening. Another notable contribution to botanical bacteriology has been the demonstration of the nature of pear blight, one of the most destructive diseases of apples, pears and kindred fruits.

Not only bacteriology, but vegetable physiology and pathology, have reaped large accessions from the work of the stations in botany. Through the work on plant diseases mycology has been enriched. Important contributions have been made to our knowledge of prunicolous Exosacæ of the United States. Research brought to light some undescribed species and several European ones not heretofore known to exist in this country. Investigations on the diseases of forest trees have been in progress for some time and connected therewith have been studies on the development of certain trees with a view to determining the rate of growth, distribution and fertility of seed, as well as the conditions which influence or modify the life of these trees. Various pyrenomyces have been studied with a view to tracing their development and polymorphism and to ascertaining the relationship of certain pycnidial and conical forms. A greenhouse pest (*Aleurodes vaporariorum*) was first reported from the United States. Original analyses made in the chemical laboratories of the stations have added largely to the scientific knowledge of economic plant foods, dairy products, fertilizers and other agricultural materials. Among the purely chemical investigations have been the isolation of the different proteins of seeds and cereals and their examination as to elementary composition and properties; studies of the development of the constituents of wheat during the growth of the plant;

investigation of the constituents of the nitrogen-free extract of feeding-stuffs; and systematic chemical studies of staple crops, such as maize, cotton, alfalfa. Among the horticultural investigations which are of most interest in their practical as well as scientific aspect are those relating to the introduction of new kinds and varieties of fruits in different localities and the increase in hardness through grafting. Experimental vineyards such as that of Georgia in our illustration are common. The introduction and testing of useful trees has resulted in a broader knowledge of the habits of many useful species from Chile, South Africa, Austria, Algeria, etc.

In testing varieties of vegetables and small fruits, and in making studies in varietal improvement and synonymy, the stations have aided materially in building up horticultural science. The special studies of problems relating to meteorological phenomena and climatic conditions have resulted in additional data of great value to meteorological science.

For purposes of verification or demonstration one cannot lose sight of the fact that material aid has been rendered by the thousands of co-operative agricultural experiments now annually carried on in the United States in which farmers take part. For these the station usually furnishes the plans of work, and the seeds, fertilizers, fungicides or other materials required, and also makes the chemical or other examinations of the soils, fertilizers or crops necessary to determine the data or results sought in the experiment. The farmer on his part furnishes the land, orchards, labor, etc., most commonly without charge.

In order that the farmers, who otherwise might be unfamiliar with the results of agricultural investigation, might the better understand what the stations are doing, it has been found necessary to issue publications giving them the complete information. In this way there has been built up a literature of agricultural science for America which did not exist a few years ago. The relation of this work of publication to the promotion of agricultural science is understood when it is known that it includes abstracts of the bulletins and annual reports of our stations, the publications of the United States Department of Agriculture, books, journals, and miscellaneous publications containing reports of investigations in agricultural science in different countries of the world; special articles by American and foreign experts in agricultural science; editorials on important matters regarding the progress of agricultural education and science, with suggestions of lines of inquiry for our stations, and notes on the organization, equipment, and development of institutions for agricultural education and research at home and abroad.

By the application of science to agriculture, and by the aid of scientific research, it is believed with good reason that the agricultural arts will enjoy a renaissance and be lifted into a position of permanent popularity and financial prosperity among the industries of America. On the other hand, the effect of agricultural education and research has been to give an impetus to general science and to attract to agricultural science the respect and attention of scientists and educators engaged in other lines.

POSSIBILITIES OF AMERICAN AGRICULTURE.

By Prof. H. W. WILEY, of the United States Agricultural Department.

THE United States, in respect of the great industries in which its people are engaged, is essentially a food producer. In this term, however, must be included the production of the raw materials for clothing, since the production of food and clothing are the two great branches of agricultural industry.

It is true that our country, during the last decades, has made wonderful progress in manufacturing, but this progress has been made possible because agricultural products are abundant and cheap. While, therefore, we pay our laborers more per man per day than is paid in any other country, we get a higher return for the investment. It is a truth universally conceded that the best paid, best fed and best clothed laborer gives the best work, so that, in reality, it is doubtful whether, measured by the amount of work produced, American labor is any higher paid than the labor of any other country.

Our rapid growth in population and the continued demands made upon us by other countries for agricultural products, have naturally raised the question whether this country in the future will be able to meet the demand made upon it from the agricultural side. We are feeding now nearly eighty millions of people within the boundaries of our own country, and sending enough material abroad to clothe and feed an almost equal number. Our foreign markets for agricultural products are the great source of wealth and preserve for us the favorable balance of trade which determines whether a nation is growing richer or poorer. The economic question, therefore, of preserving these foreign markets appears to be one of the highest import.

The statistician looks forward a few years and sees our population doubled. If, during that time, no great advance is made in agriculture, it is evident that all the products of our fields will be needed at home and we will no longer be receiving the tribute from foreign countries for these products which has made us such a wealthy nation. It is the part of wisdom, therefore, to forecast the possibilities of American agriculture, and see what relation it will bear to the progress of our country in population and industries.

In the first place, attention should be called to the fact that no country in the world has so richly endowed agricultural research as the United States. For the support of agricultural experiment stations in the various States and Territories of the United States and for Hawaii and Porto Rico the Congress of the United States appropriates annually \$789,000. In addition to this Congress has endowed agricultural colleges in every State and Territory, and these endowments, together with the buildings, apparatus, machinery, libraries and miscellaneous equipment, represents a total of \$53,632,852.25. The total income of these institutions annually is \$6,008,379.20, of which amount there is given annually by direct grant of

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