SCIENCE

FRIDAY, JANUARY 7, 1916

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

BOTANY IN RELATION TO AGRICULTURE[1]

IT is the aim of this discussion not merely to show the relation of botany to agriculture, but also to point out on the one hand what botanical investigation has actually done for American agriculture, and on the other, how recent agricultural development has stimulated the science of botany along both educational and investigational lines.

Though much of its practical application passes under such titles as agronomy, horticulture, animal and dairy industry, and soil technology, scientific agriculture depends primarily upon the three fundamental sciences of chemistry, zoology and botany. Of these, botany should and does have the closest relationship with it. This is indicated by the fact that out of 5,500 persons concerned with agricultural teaching and investigation in the U. S. Department of Agriculture and the various agricultural colleges and stations, about 700, or 12 per cent., may be classified as botanists.

There are botanists, however, who are so engrossed in the pure science of their subject that they have little interest in its economic, or, what to-day is almost the same thing, its agricultural relation; on the other hand, there are those working on the practical side who do not appreciate how much the pure science of botany has aided them in their work. We have no quarrel

[1] Address of the vice-president and chairman of Section G, Botany, American Association for the Advancement of Science, Columbus, December, 1915.

with the former, for whether they realize it or not, all scientific discovery has its ultimate practical bearing. Neither have we any apologies to offer for the so-called practical botanists, for they are the botanists of to-day in the United States, as shown by number of positions occupied and of articles published.

What, then, of this agricultural botany and the factors concerned in its development? Let us first take a brief glance at the closely related subject of the development of agriculture.

AGRICULTURAL DEVELOPMENT

Early History.—Agriculture is unquestionably a fundamental factor in the growth of a nation, therefore as a practise it goes back to the time when men first banded together into societies. But real scientific agriculture, especially as an educational movement in our colleges, is of comparatively recent origin, even more recent than that of botany. Its first educational agencies in this country were a few agricultural periodicals and the various agricultural, horticultural and allied societies that were organized to meet the demands of their time and locality. Schools of agriculture were lacking, and even instruction in existing educational institutions was not provided. Apparently the first or one of the first agricultural schools was that established by the Golds, father and son, at Cream Hill, Connecticut, in 1845, and continued until 1869. About the time of the founding of this school, Norton was appointed professor of agricultural chemistry at Yale, and among his early students were Brewer, the agriculturist, and Johnson, the chemist, both of whom later played such a prominent part in the development of our scientific agriculture. The Bussey Institution of Harvard, although provided for many years previously, did not begin its agricultural work until 1870; but in its earlier publications appeared the investigations of Storer in agricultural chemistry, the work of Farlow with plant diseases and that of Sargent in the Arnold Arboretum. In 1875 Hilgard began his work in California, and in 1880, Henry, in Wisconsin. All of these men were either directly or indirectly interested in botany.

Agricultural Colleges.—The first important factor in this agricultural development, however, was the Morrill Land Grant Act, signed by President Lincoln in 1862, which during the next few years resulted in the founding of our various state universities and agricultural colleges. To-day each state has its university or its agricultural college well established, and many states have both, either as separate or united institutions. Several of the Southern States also have somewhat similar schools of agriculture for their colored population. The various states have backed these institutions with financial aid which now in many cases exceeds that given by the government. For example, one state in its recent biennial appropriations gave to its state university, which includes the agricultural college, five million dollars.

Our agricultural colleges now compare very favorably with those of engineering and arts and science in number of students, professors and courses given. Yet twenty-five years ago they had few students, and a professor of agriculture, another of horticulture, and one of veterinary science, together with the professors of botany, zoology and chemistry as associates, often constituted the entire agricultural faculty. What a contrast to the agricultural staff of to-day, which often exceeds a hundred members, as at the University of California, with 145, Iowa State College with 213, Michigan Agricultural College with 109, Cornell with 189, Massachusetts Agricultural College with 82, and other agricultural colleges with numbers in proportion to the agricultural development of their respective states. And what a variety of titles these educators bear! The old professors of agriculture, horticulture and botany have been largely replaced by professors of agronomy, dairy industry, animal husbandry, genetics, enology, citriculture, landscape gardening, pomology, olericulture, forestry, bacteriology, plant pathology and a score or so more.

Department of Agriculture.—The second great influence in the development of scientific agriculture in this country was the establishment by Act of Congress, in February, 1889, of a department of agriculture at Washington, and the appointment of J. M. Rusk as its first secretary in the President's cabinet. Since 1862, however, there had been a commissioner of agriculture, and there were already several bureaus or divisions. Even before this for years there had been issued from the Patent Office reports dealing with agricultural information. To-day the department of agriculture comprises, besides various minor groups, bureaus of weather, animal industry, plant industry, chemistry, soils, entomology, biological survey, crop estimates, services of forest and of states relations, and offices of markets and rural organizations and of public roads and rural engineering. To carry on the work of the department, there were in 1913 nearly 15,000 employees, and the annual appropriation was $18,000,000.

Agricultural Experiment Stations.—The third factor in our agricultural development was the establishment of the agricultural experiment stations through the passage of the Hatch Act by Congress in 1886. Even previous to this, there had existed several state stations, that at New Haven, Conn., established in July, 1877, being the first. Each state originally received $15,000 a year from the government, but some years ago this was increased by the Adams Act an additional $15,000, which goes to support the more strictly scientific work. At present most of the stations also receive state aid, which in some cases greatly exceeds that given by the government. For instance, in 1913 the total revenue of the fifty-seven stations in this country was over $4,650,000, and in the case of two of these it reached nearly half a million.

Some idea of the number of investigators employed in stations having no college affiliation is shown by the Ohio station roll, with 64, the Geneva station with 37, and the Connecticut station with 25. Of the stations connected with colleges, California has a staff of 67 employed all or a part of the time in station work, Illinois 88, Wisconsin 84, Kansas 66, and Pennsylvania 49. The literature already issued by the various stations requires one hundred feet of library shelves to hold it, making by itself a very respectable working library in agriculture.

One of the important results of the establishment of experiment stations was the stimulating effect on both the agricultural colleges and the Department of Agriculture. Up to that time the colleges, as a rule, had not taught much agriculture because they had few students; and the department had not yet begun to do much investigational work. By furnishing positions for the agricultural colleges to fill, and by bringing them into closer touch with the farmers, the number of students has been greatly increased and the standing of the colleges much improved; while the rivalry in investigational work between the stations and the department has been of mutual advantage.

Agricultural Extension.—A fourth factor that may greatly influence agriculture in the future is the establishment of the agricultural extension movement, through the Smith-Lever bill, passed by Congress in

May, 1914. One of its chief features, besides the state organization, affiliated with its agricultural college, to direct the work, is the organization of societies in the various counties, with a paid Farm Bureau agent, who shall carry direct to the farmers for practical application the teachings of the agricultural colleges and the results of the investigations of the Department of Agriculture and the experiment stations.

Whether or not this extension service will prove as valuable as have the colleges and stations remains yet to be demonstrated, but it is based in part on results already accomplished in the south. The government has backed the movement with an appropriation of $10,000 a year to each state, this to be gradually increased in proportion to the agricultural population, provided equal sums are appropriated by the state. This means that by the year 1923 there may be spent in this work in the United States over $9,000,000. In most states this will be more money than is spent by the experiment station, and in a few possibly more than is spent by the agricultural college.

BOTANICAL DEVELOPMENT

Early History.—I have gone thus fully into the history of American agriculture because I believe that botany, at least during recent years, has been fundamentally influenced by it. What has been the history of our botanical development? It began with the explorers, usually foreigners, who collected plants and sent them to Europe for identification and description. Then came our native collectors, who finally began to describe the plants they collected. These early workers were interested chiefly in flowering plants, but occasionally there was an individual who worked with fungi or other groups. Local natural history societies in time offered congenial atmosphere for the study of local floras. Eventually governmental aid was given to exploring expeditions. Usually those engaged in botanical work were men who gained their livelihood from some other profession,—doctors, ministers and even lawyers.

First College Instruction.—There were a few institutions, however, that quite early had professors who gave limited botanical instruction and carried on investigations. Some idea of this early botanical work is given by the following notes from five of our oldest educational institutions, furnished the writer by their present botanical heads.

At Harvard, our oldest educational institution, William Dandridge Peck was appointed Massachusetts Professor of Natural History in 1805, and was the founder of the present Gray Botanical Garden. He was both a zoologist and a botanist, and gave lectures in the university. Peck was succeeded in 1825 by Thomas Nuttall, who was director of the botanical garden and lecturer in natural history. Nuttall lived at the Garden, but evidently did not greatly relish his work, as he resigned in 1834. In 1842 the Fischer Professorship of Natural History was founded, and Asa Gray was appointed. This professorship has been since its foundation a botanical position, a fact worthy of mention to our zoological friends, who in these days seem to dominate all the professorships in biology.

At Yale, botany was apparently first taught to a greater or less extent by Dr. Eli Ives, who held a position in materia medica and botany from 1813 to 1829, and a professorship in theory and practise of physic until 1852. He established a small botanical garden, which has since gone out of existence. After Ives's time botanical instruction was lacking until Daniel C. Eaton was appointed professor of botany in 1864, a position he occupied until his death in 1895.

At Princeton, the first instruction in botany was probably given in the closing years of the eighteenth century, by John Maclean, who was professor of chemistry and natural history. From 1824 to 1829 Luther Halsey was professor of natural philosophy, chemistry and natural history, and from 1830 to 1854 a similar position was held by John Torrey. In 1874 George Macloskie was appointed professor of natural history, and still occupies the chair of biology as professor emeritus. It was not until a few years ago, however, that one man, Professor Rankin, gave all his time to botany, and only very recently that Shull was appointed as the first professor of botany and genetics.

So far as shown by the actual dates given me, Columbia was the first institution where botany was taught, since Daniel Treadwell was professor of natural history at Kings College from 1757 to 1760. The first professor of botany was Richard Sharpe Kissam, 1792, who was succeeded by Samuel L. Mitchill, 1793 to 1795. After that botany was apparently included under natural history until the time of Dr. Torrey, who was professor of chemistry and botany, and apparently the real founder of the science at that institution.

According to both Farlow and Harshberger, the University of Pennsylvania can claim the first real botanical professorship in this country, as Dr. Adam Kuhn was made professor of botany and materia medica in 1768. Later William Bartram was appointed to the same chair, but did not accept.

Recent Development in Colleges.—Practically all this early instruction was limited to a systematic and a morphological study of the phanerogams. Apparently it had little or no relation to agriculture, its aim being purely scientific and educational, not practical. Modern botanical instruction, so far as a single institution can illustrate it, began at Harvard in the early 70's, when, under Gray, opportunity was provided for Goodale's work in vegetable physiology and Farlow's in cryptogamic botany.

About this time, however, the establishment of state universities and agricultural colleges formed a potent agency in the development of modern botanical education; for just as surely as these have been prime factors in the progress of modern agriculture, so have they been in the growth of modern botany, at least in its economic aspects. Among the names associated with this pioneer period are those of Farlow, whose early work at the Bussey Institution was of an agricultural nature, Beal, at the Michigan Agricultural College, Burrill, at the University of Illinois, Bessey, at the Iowa Agricultural College, and later at Nebraska University, Tracy, at the University of Missouri, Havey, at Maine, and a few others.

To-day there are approximately three hundred teachers and investigators carrying on this work in our agricultural colleges and stations; while there are perhaps an equal number engaged in botanical work in the universities outside of agricultural colleges, and in other non-agricultural institutions. These, with the four hundred in the Bureau of Plant Industry at Washington, make about one thousand persons in this country engaged in advanced botanical work as a profession.

In order to gain some idea of the number of general and special students in botany, and the courses offered in the agricultural colleges as compared with those in non-agricultural institutions (including those where botanical instruction in the university is separate from that in the agricultural college), the writer recently sent out a short questionnaire to an equal number of agricultural and non-agricultural institutions, and received replies from 41 of the former and 38 of the latter. No doubt these questions were not always answered from the same point of view, but including such possible discrepancies, they show the following results:

Total attendance at reporting agricultural institutions, 62,049; non-agricultural, 70,000; an average number per institution of 1,513 and 1,842, respectively. Number of students taking some work in botany the past year, in the former 12,594, in the latter 6,354, or average numbers per institution of 307 and 167. This means that about 20 per cent. of the students in agricultural institutions took some form of botany as compared with 9 per cent. in the non-agricultural. Number of major students in botany, for the former 391, as compared with 386 for the latter, making an average per institution of 10 in each case. Number of postgraduate students doing botanical work in the agricultural colleges, 180, in the non-agricultural, 228, or an average per institution of 4 and 6, respectively. Total number of botanical courses offered, in the former 537, in the latter 336, or an average per institution of 13 and 9, respectively. Of the 41 agricultural colleges, 32 had one hundred or more students taking some work in botany, while of the 38 non-agricultural there were but 16 with this number. There were 26 of these agricultural colleges that offered 10 or more courses in botany, as compared with 14 non-agricultural; and there were 13 of the former that reported 5 or more postgraduate students as compared with 9 of the latter. In total number of postgraduate students in botany, however, the non-agricultural colleges led, due to the large number at the University of Chicago, which was responsible for 103 of the 228 reported.

Admitting that these figures, like figures in general, probably lie, still we believe that from them and the data that accompanied them certain general conclusions can be drawn, as follows: (1) That, per institution and as a whole, the number of undergraduates taking botany in our American universities and colleges is greatly in favor of the agricultural institutions. (2) That the number of students in the latter pursuing advanced and postgraduate work, however, is not any greater. (3) That the variety and number of courses offered considerably exceed that of the non-agricultural. (4) That there are a number of our non-agricultural universities that in equipment, instructional force, and courses given in the pure science of botany offer advantages equal to or better than those in the best of the agricultural institutions.

The reasons for the conditions indicated by these conclusions are: (1) That, because of its affiliation with agriculture, botany in some form is favored or required in many of the agricultural colleges; while in the non-agricultural it is generally optional, and in a number of the smaller eastern colleges is not even offered as a distinct course, being given only under "biology." The inclusion under botany of bacteriology, plant breeding and forestry, or the very close connection where these subjects have been split off from this science, and the more distant, but still distinct connection with agronomy, horticulture in all its lines and entomology, are secondary factors in furnishing in the agricultural colleges numerous students who must have some instruction in botany, and from widely different points of view, thus developing numerous courses. Finally, the chances of landing a botanical position, aside from those in high schools and the limited number in non-agricultural institutions, are greatly in favor of the man who has had at least undergraduate training in the agricultural college, since he has open to him the numerous places in these institutions, their experiment stations and the Department of Agriculture; or if he merely takes minor work in botany, and specializes in some other line of agriculture, there are open the countless positions in these allied branches, including those of the newly established Farm Bureau work.

Department of Agriculture Botany.—Turning now from the botany in our agricultural colleges to that in the U. S. Department of Agriculture, what can we say of its development and influence? It apparently had its beginnings in the Patent Office Reports and the plant collections that were deposited with the Smithsonian Institution from time to time, chiefly by the various governmental exploring expeditions in the far west. As a distinct division, it was established soon after the completion of the department building in 1868, when it was found necessary to have a botanist to complete the working force, which at that time included among others a chemist and an entomologist.

C. C. Parry was apparently the first botanist, and he wrote in his report for 1869 as follows:

> In entering upon the duties of botanist to the Department of Agriculture in March, 1869, my first care was directed to the arrangement of the large and valuable collections of dried plants received from the Smithsonian Institute.

In April, 1872, George Vasey became the botanist, and, like Parry, his time at first was largely taken up with herbarium duties. Vasey, however, soon began to publish articles dealing with flowering plants, partly from a systematic point of view, though economic studies of the grasses, of weeds, and of medicinal and poisonous plants were also made.

Although as early as 1871 Thomas Taylor, the microscopist of the department, had written articles concerning various diseases of plants caused by fungi, and even such obscure troubles as peach yellows, it was not until 1886 that the Division of Botany established a distinct mycological section, with F. Lamson-Scribner in charge. The character of his report for this year forecasted the important place that this subject was to occupy in the future development of the department. That this new work met with the hearty approval of the country was shown by resolutions adopted by various societies and sent to the commissioner of agriculture, among which was one by the Botanical Club of America.

In 1888 B. T. Galloway was appointed chief of the Section of Vegetable Pathology and Physiology, and, with A. F. Woods as assistant, was intimately connected with its subsequent development. One of the most important of the results of the Galloway regime was the reorganizing in 1901 of all the divisions of the department dealing with plant life, save forestry alone, under the new Bureau of Plant Industry. These united divisions were those of botany, pathology and physiology, agronomy, pomology and the experiment gardens and grounds, and with these were later included the Arlington Experiment Farm and some other lines of work. So far as the writer knows, the Department of Agriculture is the only institution in the United States that has recognized botany in its broadest meaning, and kept under its wing all the practical branches that elsewhere assume entire independence, or even include botany as a part of their development.

To-day the Bureau of Plant Industry has on its staff over 400 investigators doing work in the 32 groups which are under its control. These groups include such varied investigations as fruit diseases, forest pathology, cotton and truck diseases, crop physiology, soil bacteriology, soil fertility, drugs and poisonous plants, grain standardization, cereals, corn, tobacco, agricultural technology, fiber plants, seed testing, forage crops, economic and systematic botany, sugar beets, irrigation, horticulture and pomology, seed and plant introduction, etc.

One of the more recent duties of this Bureau in connection with that of entomology has been inspection work under the Federal Horticultural Law passed in 1912. This has to do with regulations, including quarantine, and inspections, to prevent the importation of injurious insects and diseases of foreign plants, and in certain cases, to limit the further spreading of those already here. Previous to this law such work had been largely restricted to local state inspection, having had its origin in the effort of certain states to limit the spread of the San José scale. This work has been, and still is, largely in the hands of the entomologists.

While botanists got a late start here, they seem to have been the chief factor in similar work in Europe, so that when a world's conference was recently called at Rome to consider the subject, it was termed a Phytopathological Congress. This nomenclature seems to have aroused certain American entomologists with fear that plant pathologists were running away with what they considered their special work. Howard voiced this sentiment a year ago in a paper before the entomologists, as follows:

> There is a tendency now to break into the solidarity of our branch of science and to unite us with the plant disease people under the term phytopathology in so far as insects affect plant life. . . . To combine them into one service would be impracticable except as work of a large agricultural institution. To combine them under one name in a branch of agricultural science is absurd!

Personally the writer believes this work is more botanical than entomological, since the hosts are plants and the pests also in part. However, the work is largely routine and semi-political, involving the passage of inspection laws and the asking for appropriations, and so is somewhat on a par with the fertilizer work of our chemical friends. Why not then allow the entomologists still to dominate in this work in America, as they seem eminently fitted for it, and thus allay their fears of being absorbed by the plant pathologists?

Experiment Station Botany.—Let us now consider briefly the third factor in our recent botanical development, namely, experiment station botany. In a sense this is Department of Agriculture botany locally applied. However, the station botanist is usually working on various botanical problems, while the government botanist is putting his whole time on a few allied problems. This becomes increasingly so as time goes on; therefore one may expect the station worker to be a somewhat broader botanist, and the government investigator more of a specialist. On the other hand, the latter often has a wide but limited knowledge of his problem over the whole country, while the former has a detailed and continuous experience in a limited region. Together these two types of investigators are able to furnish admirable solutions to most botanical problems.

To Arthur, apparently, belongs the honor of being the first station botanist, as he was botanist at the Geneva station in 1884, when he published, among other studies, his paper on pear blight; however, in 1883 Maynard, professor of botany and horticulture at the Massachusetts College, was head of the horticultural department of the Massachusetts station, and published some notes on plant diseases that year.

Most of the states, upon the establishment of their stations, merely employed the professor of botany already at work in the college, and we have mentioned the names of several. Others established botanical departments for the first time, or placed them on a more substantial footing, and to these there came sooner or later such men as Halsted from Iowa to New Jersey, Thaxter to Connecticut, Atkinson to Alabama from South Carolina, Humphrey and later Stone, to Massachusetts, Chester to Delaware, Pammel to Iowa, Nelson to Wyoming, Bolley to North Dakota, Earl to Mississippi, Jones to Vermont, Selby to Ohio, Stewart to Geneva, N. Y., and Rolfs to Florida.

To-day the botanist is a fixture at practically all the stations. Naturally some stations have been more active than others along botanical lines, and these have, besides a chief botanist, several assistants, or the work is divided into botany, plant pathology and plant breeding. For example, there are listed a dozen such investigators at the California station, and Cornell has eleven who give all or part of their time to station work; while at the Ohio station there are seven who give all their time.

Naturally one expects the station botanist to be primarily an investigator. In practise, however, he is handicapped by various other duties that limit his time for investigation. Usually he has more or less teaching to do. Then such routine work as extensive local correspondence, field, orchard and nursery inspection, demonstration tests, institute talks, and aid to state agricultural societies of various kinds, adds to his duties.

Despite these limitations, the writer has in his possession some 1,700 bulletins and reports containing articles of more or less botanical interest published by station workers during the twenty-five years he has been interested in this work. From a purely scientific point of view most of these could have been omitted, but from an educational one they doubtless all have a reason for their existence. These articles, and an equally large number published by the botanists of the Department of Agriculture, lead me in conclusion to a consideration of the investigations in agricultural botany.

Investigations: (1) *Flowering Plants.*—These may be discussed under the three general headings of Flowering Plants, Bacteria and Fungi. Naturally enough, cultivated crops have attracted most attention, but much of this investigation, though semibotanical in nature, has been made by the agronomists and horticulturists rather than by botanists. Considerable attention has been paid, especially in the past, to variety testing and to methods and time of seeding or propagating, cultivating and fertilizing, different crops, as affecting their growth in various localities.

Among the botanists who have worked along these agricultural and horticultural lines may be mentioned Bailey, with his numerous studies of a great variety of horticultural and ornamental plants; Earle, with his work with southern varieties of fruits and vegetables; Cook and Hume, with tropical plants; and others with special plants, as Mell with cotton, Carleton with wheat, Toumey with the date palm, Bolley with flax, Ball with sorghum, Stuart with potatoes, Selby with tobacco, R. S. Smith with English walnut. In this connection must be mentioned the plant introduction work carried on by the government under the direction of Fairchild and his assistants. Greenhouse problems have received attention from Bailey, Galloway and Stone.

Another line of work more purely botanical in nature was the floristic surveys made in several of the states, especially where the flora was not well known. Nelson's work on the flora of Wyoming has been perhaps as extensive and continuous as any of these. Others who have published station bulletins on the plants of their states are Earle and Mell of Alabama, Bolley and Waldron of North Dakota, Blankenship of Montana, Hillman of Nevada, Wooton of New Mexico and Bogue of Oklahoma.

Those who have made studies or tests of the trees and shrubs, both native and introduced, include Roberts of Kansas, Garman of Kentucky, Beal of Michigan, Green of Minnesota, Bessey of Nebraska, Halsted of New Jersey, Kennedy of Nevada, Wooton of New Mexico, Thornber of Washington, Murrill of New York, Burns and Jones (with his assistants), of Vermont, and Blakeslee of Connecticut.

Of course the government has done much work along these systematic lines, especially with the western flora, beginning with the publications of Vasey and continued by those of Coulter, Coville, Rose, Britton, Piper, and others. This work has now largely returned to its original home in the Smithsonian Institution, leaving only the more practical studies to the Department of Agriculture.

Starting with Vasey's economic work with the grasses, there have been many investigations to determine the most valuable hay, meadow and range grasses, and especially the conditions affecting the last. These have involved detailed studies of classification, distribution, habits of growth, environment, and chemical composition. Somewhat similar studies have been made with legumes and certain forage cacti. Among the investigators concerned with this work may be mentioned F. Lampson-Scribner, Hitchcock, Nelson, Pammel, Williams, Kennedy, Griffiths, Piper, Wooton, and Thornber.

Weeds, especially their identification, nature and methods of eradication, have been another means of keeping botanists busy, more especially in the earlier days. Particularly bad pests, such as the Canada and Russian thistles, tumbleweeds, mustards, couch grass and orange hawkweed, have received especial study. General and special consideration of the weed problem early received attention from Dewey of the department, Millspaugh of West Virginia, Halsted of New Jersey, and Harvey of Maine. Special articles on particular weeds or lists of weeds in their respective states, have been published by botanists too numerous to mention. At first attempts were made to have laws passed regulating weed pests, but there has been little activity along this line in recent years, and such laws as exist are rarely enforced.

Seed testing has also had its share of attention from the station and government botanists. This work has included methods of identification, kinds of impurities and adulteration, and tests for germination. Laws have been enacted in several of the states relating to the sale and testing of seeds. The work, while important, has never received quite the detailed attention here that has been given to it in some of the European countries. Besides the publications of the Department of Agriculture, numerous others have been issued by the stations at Maine, Connecticut, North Carolina, New York, Kentucky, Ohio, Michigan, Iowa, Nebraska, North Dakota, and some other states.

Poisonous plants have claimed especial care from Chestnut, Wilcox and Pammel, with contributions from such others as Blankenship, Bessey and Halsted. Drug plants have been dealt with by True and his associates.

Physiological and chemical studies of plants have not had so much attention from botanists as some other lines of investigation, yet good work has been accomplished by Loew, Swingle, True, Alsberg, Kearney, Briggs, Schantz, and others of the department. Much of this work relates to soil moisture and soil solutions both favorable and detrimental to plant growth. Various station workers, as Stone, Duggar and Reed, have made investigations dealing with special problems involving physiological and chemical study. Through the cooperation of the botanists with the chemists, the general chemical composition of many plants, especially grasses, has been determined.

Plant breeding is one of the most recent lines of work that has been taken up by several of the stations. This in reality is not so new as it may seem, for various horticulturists and agriculturists, as Sturtevant with corn, Munson with fruits, McClure with sweet corn, and Hayes with wheat, and such botanists as Halsted with vegetables, Webber with citrous fruits, and Carleton with cereals, had long been interested, as shown by their publications. Recent work, however, has aroused new interest, and we may merely mention in passing that of Smith, East, Shull and Hartley with corn, Selby, Shamel, East and Hayes with tobacco, Roberts with wheat, McLendon with cotton, Groth with vegetables, Emerson and Belling with beans, Webber and Clark with timothy, Hansen with fruits, and Love with oats. Some of these investigations have aimed to solve the laws that underlie plant breeding, and others chiefly to produce more valuable strains or increased yields of the plants investigated.

(2) *Bacteria.*—Coming to bacteriological investigations, we find that, on the whole, our botanists have not taken so prominent a part in the work. This is because bacteriology as now constituted, though it deals with plants, is considered a distinct science. So, with the exception of teaching, in part, and investigations of plant diseases, bacteriology has passed mostly outside the realm of botany. In fact, as regards general sanitation and the bacterial diseases of man and animals, our botanists have never done much work. Burrill has always been interested in these lines, and one of his students, Briscoe, published bulletins on the tubercle bacillus. Chester, like Burrill, did a little work with animal diseases, and several botanists have published popular articles.

Dairy bacteriology also has remained largely a subject for specialists outside of the botanical realm, though such biologists as Conn, Russell and Marshal have done good work.

Soil bacteriology, however, has come a little closer home, and has occupied the attention of Chester, Kellerman, and a few others, while Burrill, Schneider, Moore, Kellerman, Duggar, Harding and Garman have been interested in the question of the bacteria of root tubercles on legumes.

Coming to the work with plant diseases, however, we find the botanists of this country have accomplished more in this line than all the rest of the world. To start with, Burrill was the first to prove that bacteria cause disease in plants; and, in the development of this line of work, Smith of the Department of Agriculture has accomplished results that place his name high among American botanists.

Among the many who have published articles dealing with special bacterial diseases of plants may be mentioned those of Burrill, Arthur, Waite, and Whetzel on pear blight, of Thaxter, Bolley and Lutman, on potato scab, of Smith, Townsend, Hedgcock, and C. O. Smith on crown gall, of Pammel and Smith on black rot of cruciferous plants, of C. O. Smith on walnut blight, of Jones on bacillus of carrots, of Stewart on the corn disease, of Stevens on tobacco wilt, of Manns on the oat disease, of Giddings on the rot of melons, and of Johnson on the coconut bud rot.

(3) *Fungi, etc.*—Taking up the last line of investigations, those with the fungi, one finds himself overwhelmed with the amount

of good work that has been done. If the American botanist leads in any kind of investigation, it certainly is in the study and treatment of plant diseases. One of the earliest lines of work was listing the species of fungi that were found in the different states, such lists, often descriptive, being published by Burrill for Illinois, Atkinson and Earle for Alabama, Tracy and Earle for Mississippi, Williams for South Dakota, Jennings for Texas, and Jones and Orton for Vermont.

Many botanists have made similar surveys for the destructive fungi of their economic plants, as Halsted for New Jersey, Pammel for Iowa, Selby for Ohio and Stewart for New York. Sturgis, and Stevens with his students, have been concerned with the literature of plant diseases; and Atkinson, Duggar, Freeman and Stevens have published books dealing with fungi. Farlow, Atkinson, Duggar, and some others have contributed data concerning edible and poisonous mushrooms. Von Schrenk, Hedgcock, Spaulding, Metcalf, Heald, Graves and Long have made studies of the diseases of trees and the decay of timber. Thaxter, Rolfs, Fawcett and Speare have been interested in the fungous diseases of injurious insects.

Determination of the alternate stages of fungi has been an entrancing study for those engaged in it, and special mention should be made of such work with the rusts by Arthur, Kern, Olive and others of Arthur's students. Artificial culture of fungi commenced with the early work of Thaxter and Atkinson, and now plays an important part in all mycological investigations, those of Shear, Heald and Edgerton well illustrating this type of work.

Disease resistance to specific fungi has received attention from Orton, with cotton and watermelons, Carleton and Freeman with cereals, Bolley with wheat and flax, Stuart with potatoes, Norton with asparagus, and Blinn with muskmelons.

In addition to the preceding, many studies have been made of physical injuries and so-called physiological diseases of plants. Prominent among such studies are those of Smith with peach yellows and rosette, Atkinson with edema troubles, and Woods, Allard and Chapman with calico of tobacco. Stone has contributed to our knowledge of injury by electricity; Sturgis, Bain and many others, of spray injury. Winter injury has received especial attention from Waite, Selby, Grossenbacher, Morse and others.

One of the most practical lines of work has been the so-called "squirt-gun botany," which deals with the treatment of plant diseases by spraying. Among the early investigators working along this line should be mentioned Goff with apple scale, Lamson-Scribner with grape rots, Thaxter with quince leaf-blight, Jones with potato blight, Chester with brown rot of peach, Lodeman with fruit diseases, and Galloway, Halsted, Stewart and Selby with a great variety of diseases.

As Bordeaux mixture is one of the oldest and most frequently used of the fungicides, it has received especial attention as to its composition, action, etc., in articles by Chester, Fairchild, Crandall and Lutman. In recent years lime-sulphur, borrowed from the entomologists, and first used as a fungicide in the west by Pierce and others, has been brought into prominence in the east by the work of Scott of the Department of Agriculture, and by various station botanists. The development of the self-boiled lime-sulphur by Scott is a still more recent factor in spraying.

Hot water treatment for smuts of grain first received attention in this country from Kellerman and Swingle, while Bolley and later Arthur brought forth formalin for a similar purpose; and Thaxter, the use of sulphur for onion smut. To Bolley we are chiefly indebted for the use of corrosive sublimate and formalin solution as remedies for potato scab, while Morse has used the fumes of formalin as a substitute.

Our pathologists seem to have been in their prime, however, when making detailed life history studies of economic fungi. The particular foes of each cultivated plant have received attention, though naturally those that are most common and destructive have had special consideration. If time permitted we should like to mention these more specifically. Each of our numerous mycologists has contributed his part to the work. Some few of these investigators have already passed to the great beyond, and others are gradually laying aside the work; many, however, are yet in their prime, while there are still more just coming into prominence. Of the last I would say that their standard of work is as high, if not higher, and their training better, than that of the older investigators, though the opportunities for original work grow less or more difficult with each year. Perhaps, however, I am mistaken, and it is only the nature of the work that changes, as indicated in letters to the writer from the late M. C. Cooke of England, who, with Ellis and Peck of this country, though not directly connected with agricultural botany, has greatly helped it by systematic work with the fungi. In conclusion permit me to quote these friendly sentiments of Cooke:

> For the past forty years and more I have had kindly correspondence and good feeling with botanists in the states, some of whom I claim as my pupils in mycology. From the time of Asa Gray, one of my first friends, I have had many. Half a century has passed me in the study of fungi, and I find as much still to learn, but I am too old now to do more than float over the surface, and confine myself to plant diseases. I note with great gratification the immense development of this branch of study on your side, which puts us to shame. Your experiment stations are fine institutions. . . . I care not who does the work, only I am delighted to see it is being done, and, between ourselves, to realize that it is being done by an English-speaking race and not by Germans or Frenchmen. To my American brethren, the mycologists, I am wishing God speed, and I care not how they beat us so long as they keep it up on a high level, clear of empiricism and worthy of the race.

G. P. CLINTON

CONNECTICUT AGRICULTURAL EXPERIMENT STATION

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1915

THE midyear review of mining conditions reported to the Secretary of the Interior on July 1 by the Director of the United States Geological Survey is well supported by the preliminary reports for the year. The Geological Survey is making public its usual estimate of mineral production for 1915 in the form of a separate statement for each of the more important mineral products.

A review of these statements confirms Secretary Lane's comment of last July to the effect that the mining revival is in full swing. In the western states alone the metal production shows an increase in value of more than $130,000,000 over the corresponding figures for 1914; and the year's increase in output for the principal metals measured in value is more than $250,000,000. Moreover it is not unreasonable to expect that when the full returns for all mineral products are compiled they will show that 1915 was the country's most productive year in the mining industry. The total may even reach two and one half billion dollars.

In the response to bettered conditions the production figures for copper, iron and zinc show the largest increase.

The copper mines passed all records for previous years, the 1915 output having a value of $236,000,000, or $83,000,000 more than the value of the production for 1914. The statistics and estimates received place the output of blister and Lake copper at 1,365,500,000 pounds or more than 120,000,000 pounds in excess of