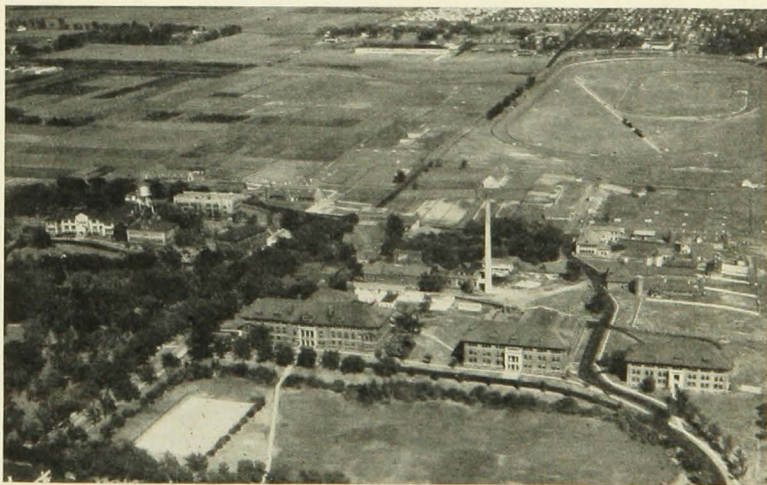


UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

MINNESOTA
AGRICULTURAL EXPERIMENT
STATION

1885-1935

ANDREW BOSS, Vice Director



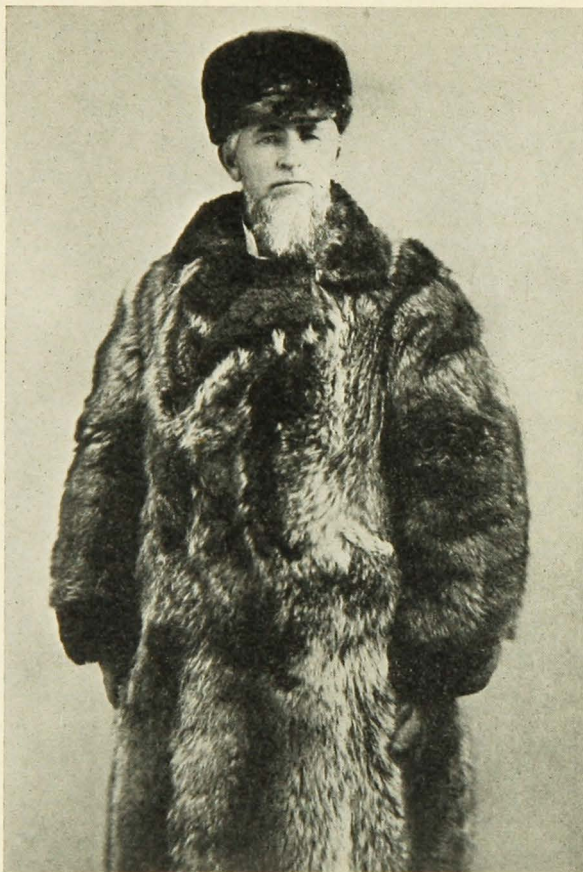
Airplane View of Experiment Station Today

UNIVERSITY FARM, ST. PAUL

This archival publication may not reflect current scientific knowledge or recommendations.
Current information available from Minnesota Agricultural Experiment Station: <http://www.maes.umn.edu>

ACKNOWLEDGMENT

The author takes credit only for the general plan of this publication and for the historical outline. He is deeply indebted to the members of the various divisions and the branch stations and to Mr. E. C. Torrey for the preparation of the summary of achievements. A subcommittee of the Committee on Achievements, consisting of H. K. Hayes, chairman; R. A. Gortner, and C. P. Fitch, assisted the author in condensing and arranging the text.



EDWARD D. PORTER

Professor of Agriculture, University of Minnesota, 1881-1889, and first Director of Minnesota Agricultural Experiment Station, 1885-1889, garbed to meet the rigors of Minnesota winters and to attend meetings with farm groups. He initiated a "new deal" in agricultural education at the University of Minnesota.

As professor of agriculture, Porter advocated the sale of the first University Farm in southeast Minneapolis and the purchase of the present farm at St. Anthony Park. He developed plans for the new buildings and for the farm layout into fields and experimental grounds. He then made contacts with farmers and with the organized agricultural groups, seeking to gain their interest in agricultural education and their moral support for adequately equipping the experiment farm. He thus laid the foundation upon which has been built four great educational movements in Minnesota, (1) the Agricultural Experiment Station, (2) the Farmers' Institutes (now Agricultural Extension), (3) the School of Agriculture, (4) the College of Agriculture.

MINNESOTA AGRICULTURAL EXPERIMENT STATION

1885-1935

HISTORICAL OUTLINE

The demand for an experimental farm in Minnesota dates back to territorial days. The pioneer settlers found many problems in their new environment. Information could be obtained only through the painful process of personal experience. The method of "trial and error" resulted as often in failure as in success.

Experimentation was too costly to be borne by the individual. Meager reports from various groups organized into societies of one kind or another contained frequent mention of the necessity for an experimental farm. Since these expressions were recorded before the establishment of experiment stations in the United States and at approximately the time of the establishment of the first experiment stations in England and Europe, they in all probability arose out of the urgent need by farmers for specific information. Records of the Territorial Agricultural Society and of the State Horticultural Society indicate that the subject was freely discussed by the groups composing these organizations.

The Territorial Agricultural Society, organized in 1854, which was then as now a federation of county agricultural societies, was the first organization actively to push the idea of an experimental farm. In the first legislative session after the admission of the Territory of Minnesota to statehood in 1858, W. S. Chowen, a pioneer farmer from Minnetonka Township, Hennepin County, introduced a bill which developed into an act for the establishment of a state agricultural college in McLeod County and provided for an experimental farm. This act was approved March 10, 1858. Specific recommendations were made for a governing board and for management of the farm.

How Glencoe Lost Out

The Territorial Agricultural Society was legalized as a State Agricultural Society in 1860. At the first meeting of the society under the new law, March 5, 1860, 12 members of the board of education for the State Agricultural College were chosen. Colonel John H. Stevens of McLeod County was elected president of the society. Thus the State Agricultural Society board and the governing board of the agricultural college and experimental farm became closely interlocked.

Colonel Stevens, who had taken great interest in the matter, actively promoted the organization. Three hundred twenty acres of land near Glencoe had been donated and funds amounting to \$10,000 had been subscribed for the erection of the first buildings, but a prevailing financial depression, the disturbed conditions preceding the Civil War, and Indian outbreaks prevented further action at that time. Colonel Stevens, chief promoter, was away in command of troops on the frontier. Governor Ramsey was in Washington on Civil War matters, and the contract which had been drawn awaited his signature. For these reasons the transaction was not completed. Interest did not die out entirely.



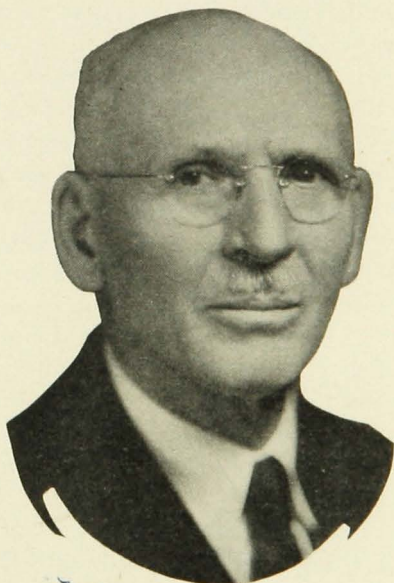
W. C. COFFEY

Elected dean and director of the University Department of Agriculture, which includes the Minnesota Experiment Station, in 1921 and still in that position. Before coming to Minnesota he served for 15 years as a member of the faculty of the College of Agriculture, University of Illinois, also serving the federal government in special capacities on call from Washington.

however, as the society elected a new board at the annual meeting in 1862 and four new members again in 1864 and in 1865.

On July 2, 1862, congress passed the first Morrill Act donating public lands for the establishment of colleges of agriculture and mechanic arts. It is possible that public agitation for the passage of the Morrill Act had prompted these Minnesota pioneers in instigating or at least hastening the establishment of an agricultural college and experimental farm at Glencoe. In any event, the state legislature in session January 27, 1863, accepted the donation of federal land and authorized the com-

missioner of the general land office to select the land. However, because of difficulty in securing funds for buildings and because of unsettled conditions during the war period, it was not possible to organize the college for educational purposes or to establish, equip, and operate the experimental farm at Glencoe. Colonel Stevens, who had been living at Glencoe, returned to Minneapolis and became less enthusiastic about the Glencoe project. Those supporting the Glencoe college then joined the supporters of the University in order to make one strong institution and to avoid dissipating the agricultural grants among the normal schools which had been strong contenders for a portion of the land-grant funds.



ANDREW BOSS

A graduate of the School of Agriculture, University of Minnesota, was appointed farm foreman, Minnesota Experiment Station, in May 1891, and has been with the station ever since. He became assistant agriculturist in 1894, associate professor of agriculture in 1902, professor of agriculture and animal husbandry in 1905, professor of agronomy and farm management in 1910, and vice director of the Experiment Station in 1917. He has held the last-named position ever since.

The First University Farm

The state auditor, who was commissioner of the state land office, estimated that the agricultural college grant under the Morrill Act would eventually provide a fund of more than \$500,000. By the terms of the act, a sum not exceeding 10 per cent of the proceeds from these lands could be used for the purchase of a site for an experimental farm. The reorganization act for the University in 1868 provided that the regents

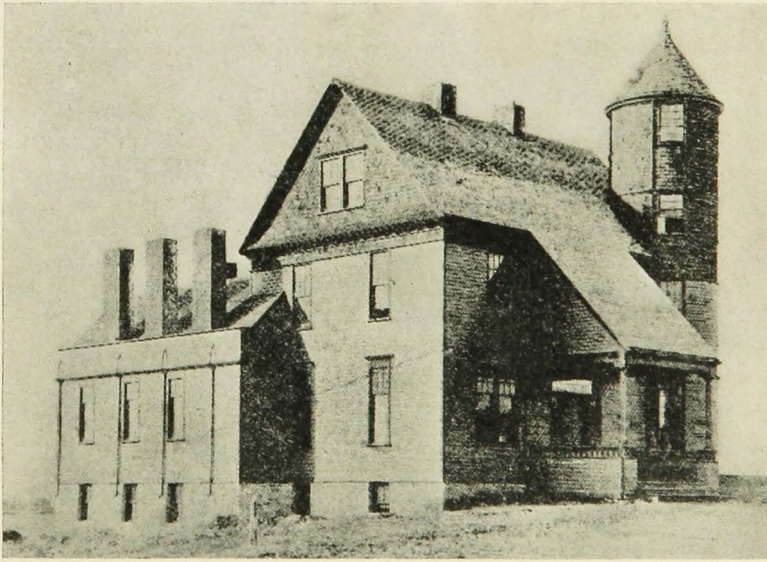
were to secure suitable land near the University for an experimental farm and authorized them to expend a sum not exceeding the amount specified in the Morrill Act. It was from these funds that the first farm was purchased. The University had been established on the banks of the Mississippi below the falls of St. Anthony, on what is now known as the "Old Campus." By anticipation of receipts from the sale of lands the regents proceeded to acquire land for the experimental farm. Proximity to the University was a prime requisite. Various tracts were examined and purchase finally made of some land a quarter of a mile east of the University Campus, extending from the present Oak Street to Prospect Park, on both sides of University Avenue.

For the first three or four years after the acquisition of the land the Board of Regents was unable to find a suitably trained person to give instruction in agriculture in the University and to take charge of the farm. Upon acquisition of the land, improvements were started and by 1869 it was reported that the enlarged farm belonging to the agricultural college had been surrounded by a neat and substantial fence and that 30 acres had been plowed and made ready for experiments. For two or three years the operations were conducted chiefly by practical farmers employed for the purpose. In 1872, Prof. D. P. Strange arrived to take charge. The production of grain and vegetables was increased, some ditching was done, and many fruit and forest trees were set out. The experiments were mostly concerned with testing varieties of wheat and oats received from the Department of Agriculture at Washington. It was at that time that the Agricultural College Building was erected on the University Campus with a "plant house" as the east wing and quarters for experimental work in agriculture in the west wing. The building was totally destroyed by fire Dec. 3, 1888.

In 1874, Prof. Charles Y. Lacy, Master of Science from Cornell University, replaced Professor Strange as instructor in agriculture and also was placed in charge of the experimental farm. Under his care the experimental work was considerably expanded, as is indicated by his reports from 1875 to 1879. He soon discovered, as others had done, that the so-called good soils of this experimental farm were not at all good and that they were poorly suited for comparative trials of crops or for testing tillage methods. He eventually urged sale of this land and the purchase of land more suitable. Becoming discouraged by inability to bring this about, by the low salary received, and by other matters, Professor Lacy resigned in 1880. The professorship of agriculture remained vacant from that time until the election of Prof. E. D. Porter in January, 1881.

The Second Experiment Farm

Upon Professor Porter's arrival, he began a study of the environment. The department had been inactive for a year, and no students were enrolled. He, therefore, devoted his time to attending sessions of the state legislature and meetings of agricultural organizations. He also initiated experimental work on the University farm and soon gained the idea, either independently or from a knowledge of Professor Lacy's recommendation and the judgment of the agricultural society members, that the farm was unsuited for experimental work and should be dis-



Original Experiment Station Building

It stood where the Old Dairy Hall, now occupied by the Lake States Forest Experiment Station, stands.

posed of. He gained the support of the regents, with the result that by June, 1882, the executive committee of the Board of Regents had negotiated for the purchase of the farm known as the Bass farm, containing 155 acres, about two miles east of the University. This Bass farm is the present University farm. Additions have been made to it from time to time, as indicated in the complete historical report. The new farm was regarded as admirably adapted to the purpose of an experimental farm and station, and the agricultural organizations of the state approved the selection.

From the sale of the old farm, which was broken up into residence lots, sufficient funds were accumulated to pay for the new farm and

to erect what were at the time considered to be adequate farm buildings. These consisted of the farm house, now known as the Agronomy and Plant Genetics Building; the Home Building, which was the original School of Agriculture Building; the farm barn, destroyed by fire in 1917, and the Experiment Station Building, destroyed by fire in 1891. The period 1883 to 1886 was devoted largely to the erection of these buildings; the subjugation of the farm, which had been poorly tilled and which was foul with noxious weeds; clearing land, erecting fences, and putting the place in order for experimental work.

With characteristic energy, zeal, and forethought, Professor Porter planned wisely and well. The unexpectedly large fund accruing from the sale of the old farm made it possible to expand greatly the work of the agricultural department. The development of the experimental farm was still closely interlocked with the authorized College of Agriculture and the rapidly developing School of Agriculture, so that it is impossible to separate completely the work of the Experiment Station from that of these other institutions. However, plantings were made of orchard and shade trees, land was prepared for plot work, and culture of various vegetable and truck crops begun, which later became the foundation for Experiment Station work.

Federal Support Won

It was at this time that agitation was manifested the country over, for federal support of experiment stations. The legislature of the State of Minnesota recognized this propaganda, and it is probable that the regents stimulated the passage of an enabling act legalizing the organization of an agricultural experiment station in the following words:

Be it enacted by the Legislature of the State of Minnesota,

Section 1. It shall be the duty of the Board of Regents of the University of Minnesota as soon as practicable after the passage of this act to establish at said University an agricultural experiment station for the purpose of promoting agriculture in its various branches by scientific investigation and experiment, which station shall be under the control and supervision of the said Board of Regents, and of which the professor of agriculture shall be the general superintendent. (Approved March 7, 1885.)

This was followed in March, 1887, by the passage of the so-called Hatch Act, or first experiment station act, by the federal congress. This provided \$15,000 annually to each state in support of experiment station work. On the passage of this act and the receipt by the University of these funds, Professor Porter immediately planned an organized expansion of the experiment station. In conformity with recommendations made by him, the Board of Regents proceeded to perfect the

organization by the election of a number of staff members. These were, in the order named, Prof. Willet M. Hays, Bachelor of Science in agriculture, Iowa Agricultural College, as an assistant to Professor Porter in agriculture. He entered upon his duties in February, 1888. In April, 1888, Prof. Samuel B. Green, Bachelor of Science, Massachusetts Agricultural College, was elected horticulturist of the station. In May, 1888, Dr. Otto Luggger was called from the entomological bureau of the Department of Agriculture at Washington to take charge of the Division of Entomology and Botany. In July, 1888, Prof. David N. Harper, Ph.B. from Yale University, was called from his position on the chemistry staff of the University of Pennsylvania to become chemist, and in August of the same year, Dr. Michael J. Treacy, a member of the Royal Veterinary College (M.R.C.V.S.) of England, was elected veterinarian. The position of accountant and recorder was filled by Daniel W. Sprague, who took office in May, 1888. Thus was completed the first experiment station organization which became the foundation of the present Minnesota Agricultural Experiment Station.

Outstanding achievements of the central station at University Farm and the five branch stations at representative points over the state are summarized on the pages that follow.

Regional Branches Established

While the early promoters of the idea of an experiment farm and station to serve Minnesota farmers were elated and reasonably well satisfied when the organization of the station on the second experimental farm was completed, Director Porter himself saw it as only a beginning. In his report of the Department of Agriculture, as given in Supplement I of the Fifth Biennial Report of the Board of Regents (1888), he made an appeal for co-operative experiments which would embrace the whole state. This appeal was expressed in the following words: "Minnesota embraces an area of 84,000 square miles, or nearly 54,000,000 acres. It is 381 miles long and 250 wide, covering 4° of longitude and 6° of latitude.

"Within this domain there is a great diversity of soil, climate and productions, and as a consequence many of the results of experimental work obtained at any one station will not be conclusive for all sections of the state. Such problems as the acclimation of plants, grains, grasses, trees, shrubs, and fruits, and their adaptations to the varying conditions of soil and climate, can only be satisfactorily solved by many repetitions of experiments in different localities."

While he was not able to bring about this expansion in full, he did impress on his associates the necessity for experiments with plants

in all parts of the state. His assistant, Professor Hays, became convinced, while conducting co-operative trials with farmers during 1890 and 1891, that it was essential for the University to own additional farms that could be operated under closer control and used to supplement and strengthen the research work of the central station. In the fall of 1891 Professor Hays was called to the position of chief agriculturist of the North Dakota Agricultural College and Experiment Station and remained there until 1893. Upon his return to the University Department of Agriculture he immediately completed a co-operative agreement with O. C. Gregg, superintendent of farmers' institutes, for the use of a part of the Gregg Farm at Lynd, Minnesota. This farm is referred to in the literature of the station as the "Coteau Farm," taking its name from the coteau hills adjoining. This farm temporarily provided for experiments in the southwestern part of the state.

It was felt that farms were needed in other parts of the state, however, and explorations were at once made for locations. In the year 1896 an additional farm was obtained a mile and a half east of Grand Rapids in Itasca County, to represent the cut-over timber region of the state. This was organized as the North Central Branch Station. The same year, 480 acres were donated by James J. Hill of the Great Northern Railway for an experiment station farm just west of Crookston. This was to be known as the Northwest Branch Station and was thought to be representative of the Red River Valley area.

With the expansion of the plant breeding work at the Central Experiment Station so as to include the small fruits and tree fruits, a suitable location for this type of work was required. After some search, two tracts of land containing 77 acres were purchased in 1907 at Zumbra Heights near the south shore of Lake Minnetonka. This unit has since been expanded and now contains 229 acres, all devoted to fruit breeding.

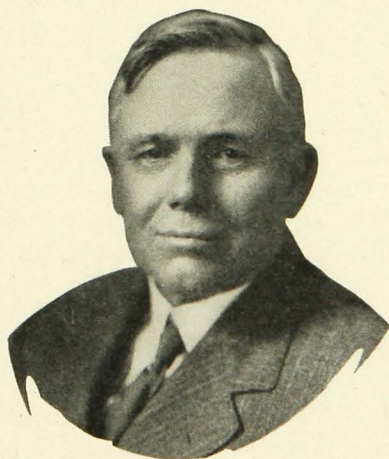
With the establishment of the School of Forestry and with increasing interest in forestry problems, a forest experiment station was deemed essential. Prof. S. B. Green, then professor of horticulture and forestry, was instrumental in securing from one of the large lumber companies of the state a tract of 2,700 acres in the vicinity of Cloquet. This has been developed into a highly efficient forest unit, now consisting of nearly 3,000 acres.

There was no further agitation for additional locations until 1910, when through an act of congress, stimulated by Professor Hays, then assistant secretary of agriculture, the land and buildings belonging to the Indian School farm at Morris, in Stevens County, were transferred to the University of Minnesota and organized as the West Central Branch Station. During the legislative session of 1911, at the request

of citizens of the state, the legislature appropriated funds for the establishment of additional experiment farms, one at or near Waseca, now known as the Southeast Branch Station, containing 246 acres; the other known as the Northeast Branch Station, just north of Duluth, consisting of 252 acres.

The Coteau Farm, established in 1893 through co-operative agreement, was abandoned in 1903. This section has since been served to a considerable degree at least, by extending the activities of the central station and the southeast branch station to meet the most pressing problems of southwestern counties. Many additional experimental fields varying in size from 2 to 40 acres have been operated, under lease, by soils, agronomy, and other divisions for the investigation of problems of a localized nature.

As now organized, the research work of the branch stations and of the central station is closely co-ordinated. Investigations in most cases are conducted under co-operative agreements and carefully considered project outlines defining objectives, procedures, and responsibilities of the co-operating parties. Investigations of local problems may be undertaken by the branches independently upon presentation of a project outline and with approval by the administrators of the central station.



A. F. Woods

Director of the Experiment Station from 1910 to 1917. Resigned to become president of Maryland State College; later the University of Maryland. Now with United States Department of Agriculture.

AGRICULTURAL BIOCHEMISTRY

Research centered first in problems of the preparation and handling of silage, in studies on the chemistry of wheat, the ensiling of clover, the sugar content of beets, and the raising of sorghum for syrup production. All this was pioneer work, much of it dating back to 1888, and was of major importance to farming and industry.

Work of Harry Snyder Outstanding

In 1891 Harry Snyder was appointed chief of the division and under his direction for 18 ensuing years remarkable advances were made along many lines, particularly with reference to the milling qualities of wheat varieties, the adaptability of flour from different wheats for bread-making purposes, the nutritional values of various farm crops, the nutritional requirements of plants, the chemical composition of dairy products, the bleaching of flour and its effect on the nutritive value.

All these studies and many more which might be mentioned brought to Professor Snyder international recognition as an authority on the chemistry of wheat products and agricultural chemical work in general. The Minnesota Agricultural Experiment Station was recognized as a leader in these fields of research, as well as in devising analytical methods and new laboratory technics that in time became standard methods generally used in chemical laboratories.

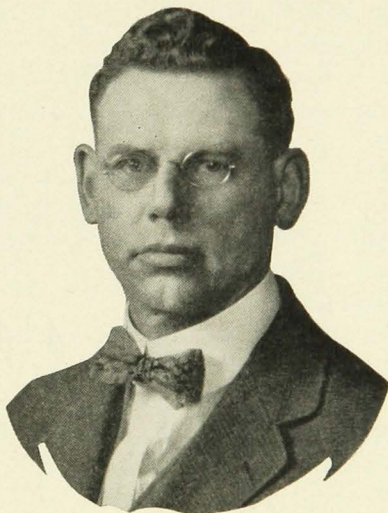
Colloid Chemistry

In this field, which is one of more recent development, the work of the biochemists of the Minnesota station is recognized internationally as having contributed new technics and new fundamental concepts. In the application of colloid chemical principles to the science of practical agriculture this station has always been a leader. In 1922 it was shown that hardiness of winter wheat was intimately associated with the colloid behavior of the plant tissue fluid and that in the winter-hardy variety the colloids "bound" the water so that it was present during the dormant condition of the plant either in a form that did not freeze, or, if it did freeze, it did not disrupt the protoplasm and kill the cells. Results of these studies have been confirmed here and at other stations. They have been extended to problems of animal and insect physiology, and the findings have been generally accepted by scientists the world over as demonstrating a new physiological concept.

From 1928 to date, a major project has been a study of the electrical properties of colloid particles within the cell, which, it had come to be realized, have a profound effect upon plant and animal growth.

Another fundamental study of recent years concerns the chemical

analysis and the nature and behavior of proteins, both from plant and animal sources. In this field, as in others, the station is conceded leadership in the development of new methods and ideas, many of which have been incorporated into the analytical program of other experiment stations.



R. W. THATCHER

Director of the Experiment Station 1917 to 1921, after serving as chief of the Division of Agricultural Biochemistry. Resigned to accept the directorship of the New York Experiment Station, Geneva, N.Y., later becoming president of Massachusetts State College, Amherst, Mass. Died in 1933.

Cellulose and Wood Studies

Research in this field has been in progress since 1925 to determine the effect of various chemicals on the pulping of wood and on the quality of the cellulose or wood pulp which results from the pulping operation. The object is to ascertain what factors are involved when the different chemicals are present, with the hope that having the necessary data it may be possible to control the pulping operation so as always to produce a uniform product. The problem, then, concerns the use of the state's tree crops, particularly of aspen, or poplar as it is more commonly known.

These investigations have also dealt with the use of aspen wood in the production of cellulose. Data already obtained indicate that aspen can be used for the production of a high-grade cellulose at a cost that will permit competition with the woods that are now more generally utilized for pulp.

Cereal Technology

Studies of wheat and other cereals have been carried on at this station ever since its establishment. The station's first bulletin, published in 1888, referred to the wheat experiments then in progress. The equipment for technological work in this field was meager, and the studies were first carried on in co-operation with a local milling organization. Typical samples of the leading spring-wheat varieties were subjected to milling tests and their flours were studied by means of the "baker's sponge test" to determine their comparative baking value. Gluten tests were also made.

In 1901 an experimental flour mill and "test baking" equipment were added to the facilities for conducting flour milling tests of wheat samples. This equipment, pictured as a pair of corrugated rolls, a pair of smooth rolls and a sifter, is still in regular use after 34 seasons of rather strenuous operation.

Projects involving the milling value of wheats, the chemistry of milling and baking, flour bleaching, and the nature of flour proteins were carried on for several years under a co-operative arrangement with the State Grain Inspection Department and resulted in the making of annual surveys to determine the average quality and variability of Minnesota wheats. This resulted, in turn, in estimating the properties of the several varieties, both spring and winter; in identifying the superior quality of Marquis wheat when it was introduced from Canada; in warning growers against inferior wheats; in helping to sort out the superior wheat hybrids from the inferior ones, thus markedly influencing the wheat production of this general area.

During many years cereal technologists have co-operated with plant geneticists in the testing of new wheat productions. Thus the new double-cross variety named Thatcher was selected as a promising bread wheat of excellent milling and baking qualities.

Students come from all parts of the world to join the attack on such problems as the phenomenon of rancidity of fats and oils and its control, uses of milk products in baking, cracker baking, respiration of cereal grain, enzymes of yeast and flour in their relation to baking processes, and the constitution and properties of cereal proteins and carbohydrates. The Minnesota station occupies a strong position in the vanguard of the institutions that have engaged in such activities.

Dairy Chemistry

The most important of the early contributions in the broad field of dairy chemistry were the extensive chemical analyses of milk, butter,

and cheese made and published by Professor Snyder. Out of this work developed his "Textbook of Dairy Chemistry," which was the first text on this subject published in the United States.

Major problems under attack have had to do with milk enzymes, powdered milk, cream rising, coagulability of milk by rennet, butter structure, and the nature and properties of the substances adsorbed on the surface of the fat globules of milk. It was discovered that normal cow's milk contains little if any fat-splitting enzyme, but that milk from cows in advanced lactation often contains enough of the ferment to cause the milk to become bitter in a few hours, even when kept cold, and also to cause the cream and butter to become rancid and unfit for use. Peroxidase, abundant in normal milk and destroyed only by high-temperature pasteurization, was not found to be a factor in the keeping quality of dairy products containing this enzyme.

Powdered whole milk studies revealed that the microscopic structure of powders manufactured by different methods is related to their keeping quality, those powders whose particles have a spherical structure, possessing a central air core, being more prone to undergo subsequent oxidation. Milk powder when reconstructed into milk was found to produce a milk that can scarcely be distinguished from natural milk so far as chemical and physical properties are concerned, provided the powder is manufactured properly.

In cream-rising studies made recently it was shown for the first time that the colloidal constituents of the whey and the skimmilk were major factors involved in determining adequate or inadequate rise of the fat globules and large or small volumes of cream, the colloids of the whey favoring normal cream rise, and those which are removed from the skimmilk in forming the whey having a retarding effect. The sugar and soluble salts of milk were found to be unimportant factors in this phenomenon.

New facts have been brought to light on the rôle of the colloidal minerals of milk in producing the clotting phenomenon. Previous theories as to the rôle of the albumin of milk in this clotting by rennet have been refuted. Extensive studies have been made of butter structure and the colloid chemistry of churning.

Investigations regarding the nature and properties of the substances adsorbed on the surface of the fat globules of milk have led to the first correct understanding of the rôle played by the complex colloidal structure of milk. It has been found possible to wash away from cream all the materials which characterize the skimmilk and leave a cream which has all the important properties of natural cream.

Animal Nutrition

The nutritive value of animal feedstuffs and human foods was emphasized in the early investigations of the station chemists. As significant facts developed regarding grains, forage crops, and new feedstuffs coming into use, such as linseed meal, they were passed on to the livestock growers of the state. Some work was done on pasture grass and the Russian thistle, a weed fed to some extent in certain localities.

In the field of human nutrition special attention was given to breads made from different grades of flour and to the nutritive value of vegetables, cereals, legume seeds, cheese, butter, oleomargarine, and bacon. A bulletin prepared by Professor Snyder and published in 1897 is still regarded as one of the outstanding publications of its time in this particular field.

In 1913 the present Division of Agricultural Biochemistry was organized, a new staff developed, and a new era of nutrition research entered upon. A definite program was launched and a series of co-operative studies begun with other divisions of the station. In this co-operative work attention has been given the vitamins in cow's milk, the vitamin requirements of calves, and the mineral needs—especially calcium and phosphorous—of dairy cattle. The late Dr. Clarence Henry Eckles was actively associated with these studies. The Minnesota station was among the first to prove that the vitamin content of cow's milk varies with the ration fed and to show what types of rations must be given in order to maintain the vitamin content of milk at its highest level under practical conditions.

Mineral Requirements Adjusted

The contributions of the station in the field of mineral nutrition have been especially noteworthy. Particular attention has been given to the elements phosphorus and calcium. The natural occurrence of phosphorus deficiency among cattle in Minnesota has been shown to involve nearly one-half of the state. The lowered efficiency of nutrition and decrease of productiveness both in milk flow and in calf crop, which touch many thousands of dairy cattle in the state to a greater or less extent, annually result in financial losses of great magnitude. The conditions are especially severe following drouth, when the forage contains insufficient phosphorus to supply even the maintenance requirements of the animal body. As a result of these studies, recommendations have been made to farmers whereby these conditions may be prevented.

An important feature of the phosphorus deficiency problem, recently completed, was the discovery that the decreased calf crop in certain lo-

calities, which had been attributed to a disturbed estrum or heat, is not due primarily to the phosphorus deficiency, but to other accompanying nutritive deficiencies, the nature of which is now being investigated. As to the calcium requirement, it has been established that cows do not abort because of lack of this mineral in their rations. It has further been shown that improper methods of calf feeding often result in serious calcium deficiency.

A nutrition problem which has been studied intensely and is still under attack concerns the differences among individual animals in the utilization of food for growth. These differences, it has been found, are under the control of physiological factors which are inherited.

AGRICULTURAL ECONOMICS

The first phase of research to receive attention was farm management. Interest in the subject manifested itself in the nineties as an outgrowth of work in agronomy and was carried on in the Division of Agronomy and Farm Management until 1928. In November, 1911, the Board of Regents authorized the creation of a "Bureau of Research in Agricultural Economics." The bureau was established on February 1, 1912, and later became the Division of Agricultural Economics. In 1928, the activities were combined in a new Division of Agricultural Economics.

Farm Management

The Minnesota Agricultural Experiment Station was a pioneer in the study of the business side of farm problems. The experimental work of W. M. Hays, Andrew Boss, and their associates with crops and crop rotations impressed upon them the importance of information regarding costs and returns as a basis for planning cropping systems. During the nineties some attention was given to the possibility of using cost records from fields and plots on the experiment station farm as the source of information. While the data thus obtained were not representative of costs under actual farm conditions, this beginning undoubtedly was useful in laying the foundation for the future research program in this field.

In 1902, the station in co-operation with the Bureau of Statistics of the United States Department of Agriculture started the use of statistical routes for the gathering of farm-management data. Station Bulletin 97, "The Cost of Producing Farm Products," appeared in 1906 and was the first formal publication of detailed results of these studies. Accounting routes have been continued as an integral part of the farm-

management research program since its inception. The early work furnished the basis, and methods have been constantly improved. These studies have been carried on with farms representative of different types of farming in different sections of the state. The results have been invaluable in throwing light upon problems of farm organization and management.

Of this early work Sigmund von Frauendorfer, a distinguished authority, said in the *Journal of Farm Economics* of July, 1928: "It required the initiative of energetic and far-seeing men to raise farm management to the rank of a clearly defined and generally recognized science. The first of these men who can be called the pioneers of American agricultural economics was W. M. Hays of the University of Minnesota."

The work in farm management has not been restricted to statistical routes of the intensive type. A project involving a larger number of farms and less detailed records has been developed for a study of factors affecting the income of dairy farms. Farmers co-operating in this project recognize the immediate benefits they can derive from such a study and contribute towards the cost of the work through the payment of an annual fee. Survey methods also have been used at various times in collecting farm-management data. Types of farming in various parts of the state have been studied and types of farming areas have been mapped. Farm leases and a variety of other important problems of farm management have likewise been made the subject of investigation.

Work with farm records emphasized that not all of the differences between the results obtained on different farms are explained by differences of the farms or farm organizations. Some are accounted for by differences in individuals—in the human factor. One of the first comprehensive studies of the part played by the human factor in farm management was carried on by the Division of Agricultural Economics in co-operation with the Bureau of Agricultural Economics of the United States Department of Agriculture.

Marketing

When the "Bureau of Research in Agricultural Economics" was established in 1912, the first problems to which attention was devoted were in the field of marketing. Research work in marketing was a new development at that time, consequently the Minnesota station was among the pioneers in this field as well as in farm management. The "Office of Markets," established in the United States Department of Agriculture in 1913, was that department's first extensive attack upon marketing problems. The first comprehensive textbook on agricultural marketing was an outgrowth of research work at Minnesota.

The work in marketing research has continued with improvements and refinements. The earlier studies were largely descriptive of marketing methods and agencies. As the work progressed, more attention was paid to analysis of problems and the development of suggestions for effecting improvements. One of the earliest comprehensive surveys of co-operative associations was made by this institution. According to this survey, there were about 2,000 co-operatives in Minnesota in 1913, doing an annual volume of business of more than 60 million dollars. Surveys were conducted of specific kinds of farm co-operatives, such as co-operative creameries, farmers' elevators, livestock shipping associations, and the like. These early studies have been followed by others directed at the organization and operation problems of co-operatives of various kinds. Among the marketing questions to which attention has been given is that of the importance of foreign markets for American agricultural products. Results of these studies have been made available to farmers and others through publications and extension work.

Agricultural Prices

Research work in prices can be carried on extensively only in institutions possessing man power and equipment necessary for the compilations and analyses involved. The Division of Agricultural Economics has occupied a prominent place in such research. A study of factors affecting potato prices was among the first comprehensive statistical analyses of agricultural prices and was an important influence in stimulating further research in this field. Additional studies carried on here have related to such farm products as corn, hogs, and butter. Studies of local prices have been made. Studies of factors influencing the demand for farm products, particularly dairy products and meats, have supplied information of value to purchasers, consumers, and marketing agencies.

Farm Credit

Attention has been given to farm financing problems during the last 20 years by this division. Studies have been made of credit sources and facilities, mortgage foreclosures, debt adjustments, and related problems. These studies have thrown light on needed improvements in farm credit and have been very useful in suggesting ways and means of debt adjustment during the present period of economic distress.

Land Use and Values

Factors affecting the prices of land have been analyzed. Studies have been made of the sale prices of land and the factors affecting them over a long period of time.

One comprehensive study in the field of land use is that recently completed, the results of which have been published in "A Program for Land Use in Northern Minnesota" (University of Minnesota Press, 1935). This study was made in co-operation with the federal Bureau of Agricultural Economics, various divisions of this station, and other agencies. It considered the problems of the cut-over area of northeastern Minnesota, not only to ascertain the situations needing attention but also to develop practical lines of action designed to effect improvements. Among other things, it presents a tentative classification of the region into land-use areas and makes specific suggestions regarding policies and programs of land use for the future.

Taxation

A comprehensive study has been made of the relationship between assessment of farm land and sales value of the land, the results pointing clearly to opportunities for improvement in the accuracy of assessment. Surveys have been made in representative areas to determine the tax burden of farmers in relation to income.

AGRICULTURAL ENGINEERING

The research work is organized under three principal sections known as land reclamation, farm structures, and farm power and machinery.

Reclamation

The efficiency of tile drainage in different types of soil on the farms of the state has been proven. Effective and economical spacing and depth of tile drains in flat lands, as fixed by the physical characteristics of the soil, has been determined, as well as the most effective and economical methods of farm drainage installation. Information has been made available regarding the degree of drainage required in peat lands for optimum development thereon of different types of crops. The initial investment in tile drainage on farms has been analyzed in simple, fundamental units.

In co-operation with the United States Department of Agriculture and the Minnesota State Department of Conservation, staff men discovered that by curing Portland cement concrete drain tile in steam at temperatures between 212 and 350 degrees F., resistance of the tile to the action of sodium sulphate increases almost to the point of immunity and greatly raises resistance to attack by magnesium sulphate. These two soil alkalis are common to sub-soils of western Minnesota and have been particularly destructive to concrete tile systems.

Research also established the fact that concrete drain tile made of highly resistant Portland cement will last nearly ten times as long as that made of a cement of low resistance under identical conditions of exposure to the soil alkalis. A routine test was devised for determining the resistance factor of a cement. Standard tests have been devised, which enable the prediction, within reasonable limits, of the frost resistance of clay tile produced by any one of 23 Minnesota and Iowa manufacturing plants that furnish practically all clay drain tile used in Minnesota, thus greatly simplifying and stimulating the testing of clay tile. The direct effect of this work has been to improve definitely the quality of clay tile sold in Minnesota.

In co-operation with the Division of Forestry, the agricultural engineers conducted research in timbered swamp areas in peat bogs of northern Minnesota, to determine the effect of drainage ditches on forest growth, establishing the fact that growth was stimulated along the ditches and reached its maximum where the drainage was the most thorough. No injury to tree growth because of excessive drainage of the peat bogs was found.

Farm Structures

The work in farm structures was organized about 20 years ago. Nearly 250 plans for farm buildings of all sorts have been prepared. Thousands of copies of these plans have been sent out, and many buildings on farmsteads have been erected by their use. These plans have also been used by business organizations dealing in building materials, and thus the standards for houses and other farm buildings have been improved.

Impressive contributions have been made to modernizing country homes. Many such homes today have furnaces, running water at the laundry tray, kitchen sinks, and bathrooms. They have modern lighting, either from a small farm electric plant or a high tension electric line. This has made possible such equipment as electric refrigerators, vacuum cleaners, washing machines, and other modern appliances about the house, and electric pumps and handy motors about the farm yard. Examples of the amazing advance from the primitive conditions of 50 years ago are to be found everywhere in the state.

Farm Power and Machinery

The Minnesota Experiment Station has played an important part in determining standards of farm equipment design. Much information has been obtained of the costs of using tractors of various sizes for

various farm operations, as to kinds of work for which the tractor is best suited, and the optimum loads for tractor operation. Tests have been made of new farm machines, such as the combine harvester and the field ensilage harvester, in order to enhance their usefulness under conditions existing in this state.

Practices and costs of various phases of land clearing have been studied here. Detailed information has been obtained as to the cost of the stump and brush removal on different types of soil. The most economical methods of disposing of field stone under different conditions have been determined. Costs and methods of preparing fuel from pine stumps have been worked out.

Station engineers had charge of the distribution of about 10 million pounds of war salvaged explosives, made available by the federal government for the use of Minnesota farmers in removing stumps and field stones. It is estimated that this project saved the farmers about one-half million dollars.

AGRONOMY AND PLANT GENETICS

Minnesota was an early leader in the development of plant breeding in the United States. Investigations were initiated at Minnesota in 1888, the year after the Agricultural Experiment Station was established. These developments were a result of the breadth of vision of Willet M. Hays, who, as agriculturist, was responsible for early research at Minnesota with farm crops.

Introductions of varieties and samples of wheat were made and approximately 200 studied as early as 1889. Field and laboratory methods were developed for planting, harvesting, and studying the progeny of selections, and a standardized program of breeding methods with small grains was formulated. The importance of quality was recognized, and milling and baking studies were an essential part of the early wheat-breeding program.

The importance of selection was clearly recognized. The methods adopted for self-pollinated plants consisted of an initial selection of promising individuals in fields plots and their progeny study in cent-gener plots, e.g., 100 plants. Among commercially important early productions of Minnesota plant breeders were two varieties of wheat, Improved Fife (Minn. 163) and Haynes Bluestem (Minn. 169) and Minn. No. 13 corn. Of equal or greater potential value was the emphasis on the scientific importance of attacking problems in plant breeding on the basis of learning the fundamental principles involved.

Varietal Improvement of Farm Crops

The production of improved varieties of farm crops is dependent upon a knowledge of the genetics of crops, the grower's needs, and the development of sound methods of breeding. In the development of improved varieties by hybridization, the plant breeder applies Mendel's laws of heredity directly to the problem of practical breeding. Sound statistical methods are a great aid also in an analysis of the results obtained. With particular reference to the improvement of wheat, oats, barley, rye, flax, and corn, each of the above phases of research has been carried on at Minnesota, and the reputation in plant breeding of the Minnesota Experiment Station in the United States, as well as in many foreign countries, is shown by the large number of graduate students in plant genetics who receive their training here.

An important phase of the program has been the development of disease-resistant varieties through co-operative efforts by plant breeders and plant pathologists. Through this co-operation fundamental underlying principles, including a genetical analysis of both host and parasite, have led to sound breeding methodology. Thus it has been learned that wilt resistance in flax cannot be accumulated gradually by the association of parasite with the host plant, but that the production of resistant types is a result of the selection of wilt resistance already present in the host organism.

Through greenhouse and field studies it has been learned that there is a direct relation in oats between seedling infection with particular physiologic races of stem rust and field reaction. New varieties produced by breeding are resistant to races of the rust organism most prevalent in the region. With wheat, there is not always a close relation between seedling reaction to certain physiologic forms of the disease and reaction in the field to the same forms as the plant approaches maturity. This knowledge furnished a basis for the development of improved varieties that so far have shown moderate resistance in the field to black stem rust and are satisfactory also in other important characters such as milling and baking quality and yielding ability. Smooth-awned varieties of barley that are resistant to "spot blotch" have been developed. Certain of these varieties are of satisfactory quality for malting purposes. Methods have been developed to test large numbers of inbred strains of corn for reaction to corn smut, and resistant strains have been used to produce improved hybrids for commercial seed production.

Varieties Developed and Introduced

During the last twenty years extensive investigations have been made with corn for the purpose of developing improved varieties. These studies in co-operation with other cornbelt experiment stations have led to a sound program for the production of hybrid corn seed in our state and the introduction of hybrids that excel farmers' varieties of corn by 10 to 25 per cent. Sweet corn hybrids have been obtained that excel normal varieties by 30 to 50 per cent, on the basis of quality and quantity of cut corn produced per acre for canning purposes.

Studies of particular characters of crop plants have aided also in the isolation of new varieties that excel in important characters. Thus, Mindum durum wheat bred in Minnesota has become the standard of excellence for macaroni purposes and is perhaps the most popular variety grown. Hardy varieties of winter wheat, that have been the chief reason for a large increase in winter wheat acreage in southern Minnesota, have been developed. Stiff-strawed varieties of oats and barley, which aid materially in reducing losses from lodging on heavy soils, have been obtained.

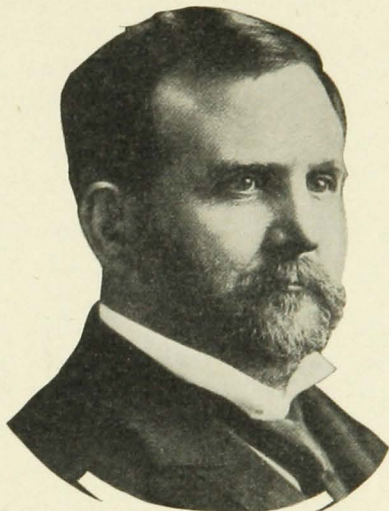
Among the varieties or crosses which have been developed at this station and released to the farmers of Minnesota since 1917 are Marquillo and Thatcher spring wheats; Minturki winter wheat; Velvet and Glabron barley; Gopher, Anthony, and Minrus oats; Chippewa, Winona, and Redwing flax, and Minhybrids 201, 202, 301, 401, and 402 corn.

The value of new productions by other stations has been recognized through trials conducted in Minnesota, and new varieties of great promise have been obtained by these means. Thus, Grimm alfalfa, produced in Carver County by a German immigrant farmer, was recognized and introduced and has helped materially in a sound crop program for the state. Sweet clover, soybeans, and reed canary grass have also been recognized to be of great value.

These accomplishments in crop breeding have been made possible by co-operative effort between agronomists, plant breeders, plant pathologists, and cereal technologists at the central station and the agronomists and superintendents at the branch stations. A yearly conference of all interested workers is held; new varieties are introduced when approved by the conference after a study of the actual results from field and laboratory trials, and an annual list of recommended varieties is drawn up by members of the conference.

The growing of improved crops on a state-wide basis requires the production of vast quantities of pedigreed seed. The Experiment Station has co-operated with the Minnesota Crop Improvement Association in the production of certified and registered seed stocks. First in-

creases of new varieties of crop plants are made on experiment station fields, and a small amount of seed of all recommended varieties is produced by the stations to serve as a first source of pure seed of the most important varieties available.



WILLET M. HAYS

Elected assistant in agriculture, Minnesota Experiment Station, in February, 1888. He was the first addition to the staff under Edward D. Porter, the lone member of the staff at the beginning. He served as vice chairman of the station, 1893-1904, and was assistant secretary of agriculture, United States Department of Agriculture, under James Wilson, 1905-1913.

A sound program of practical plant improvement can be built only on an adequate foundation of fundamental research. The fundamental phases have always received their just share of emphasis at Minnesota. Among the problems in crop genetics under this general attack have been the mode of inheritance of reaction to plant diseases; of seed and plant characters and the relation between differential characters and yielding ability; of the morphological characters of barley; of the quantitative and qualitative characters of oats; of the awn of wheat and its physiological importance; of spring and winter habit of growth of wheat and the correlation between winter hardiness and winter habit; of self-sterility of rye, and the effects of inbreeding of corn and other crop plants.

Cropping Systems

Crop rotation investigations were started in 1892 by Professor Hays who laid out four series, each consisting of 11 one-tenth-acre plots. A different system of cropping was planned for each plot, and hence a

yield of each crop was obtained only once in each cycle of the rotation. Data for a 10-year period showed that continuous cropping resulted in distinctly lower yields than rotational cropping and that there was a choice even among good rotations. Analyses by the chemists of the soils of the plots at the beginning and 10 years later showed that where cultivated crops such as corn, potatoes, and mangels were grown continuously, maximum loss of nitrogen and carbon occurred. Where a good rotation such as wheat, clover and timothy hay, timothy hay, oats, and corn was followed and eight tons of barnyard manure were applied once in each rotation, the nitrogen and carbon content of the soils was maintained.

In 1909 another rotation experiment was initiated with three series of 26 one-tenth-acre plots. Each crop in each rotation was grown every year. For the first 10-year period, wheat, oats, and corn grown in a grain, clover, and corn rotation with six tons of barnyard manure preceding corn yielded 39.2, 23.6, and 28.2 per cent higher, respectively, than the same crops grown continuously with equal amounts of manure applied.

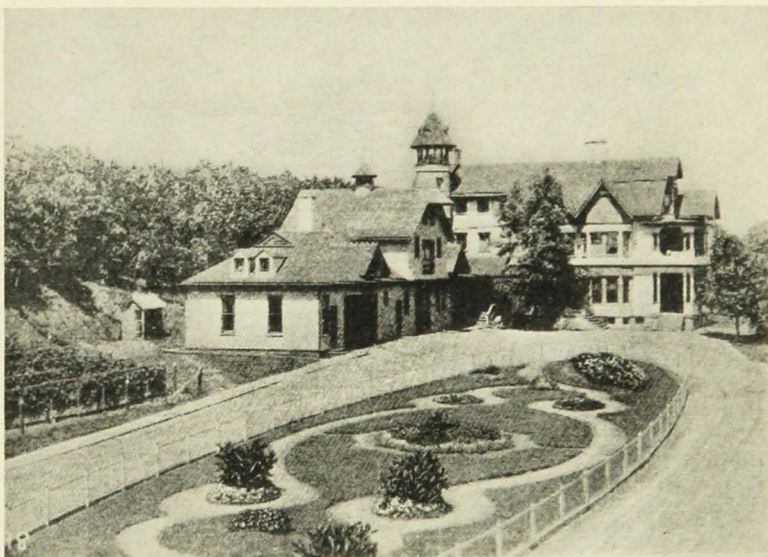
Crop Production

A study of the effects of cutting alfalfa at different stages of maturity, on the development of young plants and on the variations in root reserves and ability to survive when subjected to low temperatures, has yielded data of great value in the management of this important crop. In a study of methods of differentiating between a winter-hardy variety, Grimm, and a non-winter-hardy variety, Kansas Common, it was found that actual freezing of the hardened plotted plants or of the roots removed from the soil was the most reliable.

In a study of root and top development of sweet clover types and varieties sown without a grain crop in early spring, the determinations being made in the autumn of the same year, annual sweet clover, Hubam, produced 15 per cent more dry matter in the tops than biennial white and 35 per cent more than biennial yellow. The annual sweet clover produced in its roots only a small fraction of the weight of dry matter produced in the roots of the white and yellow biennial varieties. Biennial sweet clovers produced highest yields of dry matter in the roots in October of the same year they were planted, with some decrease up to May of the following year and then generally some increase up to the time the first crop was ready to cut for hay. The maximum total nitrogen per acre in tops and roots of biennial sweet clover was produced in October of the same year the clover was sown.

From a study of reed canary grass harvested for hay, it was found

that yields of dry matter increased and crude protein percentage decreased rapidly up to the time of full heading. Alfalfa sown alone yielded 18 per cent higher than clover alone and 63 per cent higher than timothy alone. Mixtures of alfalfa and timothy yielded 11 per cent higher than mixtures of red clover and timothy. Marked reduction in yields of small grains and flax was apparent when the sowing was delayed much beyond the time the land was in fit condition to work.



Farm House, Minnesota Experiment Station

One of the buildings used at the time the Experiment Station was established; now occupied by the Division of Agronomy and Plant Genetics.

The sowing of suitable mixtures of oats and barley resulted in higher yields of total digestible nutrients per acre than sowing oats alone, but not higher than from sowing barley alone. Likewise, sowing suitable mixtures of wheat and oats provided more digestible nutrients per acre than sowing oats alone, but not higher than wheat alone.

Weed Eradication

Chemical eradicants at different rates of application have been thoroughly tested at the station. Sodium arsenite was found effective and practical on small areas, but its poisonous properties prohibit its use in pastures. Sodium chlorate is recommended as the most reliable and practical chemical for use in eradicating small areas of perennial weeds. A study

of the methods of eradicating quack grass by tillage was carried on over a five-year period. Methods for this system of eradication and probable costs have been made public.

Variations in reserve materials from spring to fall in the underground parts of five perennial weeds were studied in 1928. Rapid lowering of the readily available reserves occurred in spring as the new tops appeared and developed, followed by increases in root reserves later in the season. Quack grass was noted as an exception to this finding for the reason that its green parts, overwintering, are ready to elaborate food material in early spring.

ANIMAL HUSBANDRY

Work has consisted largely of experiments in the care and feeding of farm animals in order to obtain information that would lead to more profitable feeding practices. In recent years, a study, on a long-time basis, of fundamental problems in animal breeding has been undertaken.

The Work of Thomas Shaw

The feeding experiments date back to 1892 when Prof. Thomas Shaw became chief of the division. His first work was a study of the use of annual crops planted for pasture. Several of the crops shown to be suitable, notably rape and rye, for sheep and hogs, have been grown for pasture on many farms ever since.

Other experiments conducted by Professor Shaw consisted largely of comparisons of different rations for the fattening of lambs and steers in winter. These trials demonstrated that the fattening of these animals on grain was a decidedly profitable practice under the conditions then prevailing and marked the beginning of a continuously expanding enterprise in lamb and cattle fattening that now constitutes one of the most important sources of income from livestock in the state.

Professor Shaw also made experiments in crossing the breeds of hogs for the production of market stock. These indicated that the cross-bred hog showed increased vigor and efficiency in the utilization of feed.

Achievements of T. L. Haecker

While generally known for his work in the dairy field, Professor Haecker served as head of both the dairy and animal husbandry divisions from about 1901 to 1915. During this period he directed an extended study of the feed consumption of growing and fattening steers, his object being to develop a feeding standard that would serve as a guide to feeders in preparing rations. He began with young beef calves

of good type and fed them a growing fattening ration based largely on the common practices at the time.

Notation was made of all feeds consumed by each steer and the daily rate of gain. Representative animals were slaughtered at intervals, determined by increases of 100 pounds in weight. The carcasses were then sampled and analyzed for their water, protein, fat, and ash content. Many feed samples were also analyzed for their nutritive content. From this study, covering a period of 15 years and involving the feeding of more than 100 calves, and the analyzing of about 70 bodies, a feeding standard was developed.

Data were obtained setting forth the progressive changes that take place in the chemical composition of the body of the steer with advancing age, growth, and fattening. This experiment was the first of its kind and stands as a classic in animal husbandry research. Data obtained indicated that in the well-fed animal food nutrients will be used largely for growth up to about 700 pounds, after which there will be a rapid deposit of fat up to a weight of 1,000 pounds. Greatest efficiency in the utilization of feed was evident up to the 700-pound weight. This efficiency held up pretty well to the weight of 1,000 pounds, but thereafter was rather markedly reduced.

The conclusion was reached that the economical feeding of growing fattening cattle, as it is now so commonly carried on in baby beef production, involves the liberal feeding of a ration high in protein content up to a weight of about 700 pounds, at which time the animal will begin to fatten rapidly and can economically be carried to 1,000 pounds, when it will show a desirable development of muscle and enough fat to produce beef of high quality.

Baby Beef Production

Experiments in the fattening of beef calves to be marketed as finished baby beefs were carried on at University Farm and the Northwest Branch Experiment Station from 1920 to 1930. In all, about 1,000 calves were fed in groups of eight or ten each. Facts were sought with which to answer questions concerning the breeding, selection, and purchase of calves to be fattened, the combinations of feeds to be used, and the preparation to be given the feeds in order to obtain the most profitable results.

These trials showed conclusively that the raising of beef cattle and the fattening of the calves at a young age constitute the most profitable type of beef cattle management for this state. As a sequel largely of these experiments, beef calves raised by the more progressive beef cat-

the farmers of Minnesota are now marketed as fat baby beeves at 14 to 16 months of age.

Fattening of Lambs

Co-operative experiments in the fattening of lambs at the West Central Branch Experiment Station for the last nine years have had a marked influence on the sheep-raising enterprise within the state. About 4,200 lambs were fattened in groups of 30 each. Results made it plain that the Minnesota-raised lamb makes just as suitable a feeder and fat market lamb as the type of lamb coming from the range states. By establishing this simple fact, a marked stimulus has been given to sheep raising on Minnesota farms.



Original Cattle Barn, Experiment Station

It stood where the present cattle barn stands. It was burned to the ground in 1917.

Swine Feeding

During the last 15 years more than 3,000 pigs have been fed in the station experimental feeding trials, some in lots of 10 pigs each, some in smaller lots, and some individually. These trials have shown that the pig, more than any other type of farm animal, requires a suitable protein supplemental feed if it is to be fed successfully and profitably. Many plans for supplying this protein supplement have been studied in the feeding trials. One outstanding fact that has been repeatedly demon-

strated is that protein from an animal product such as tankage or the milk products is decidedly more effective than is protein from the vegetable products such as linseed meal, cottonseed meal, and soybean oil-meal. Superior results are nearly always secured when protein from an animal source comprises at least 50 per cent of the total amount of protein supplement.

It has been found that while alfalfa hay fed in winter and green pasture supplied in summer contribute satisfactorily toward raising the protein content of hog rations, these feeds do not supply enough protein or complete enough proteins to supplement fully the farm grains and that additional protein must still be supplied if best results are to be secured. When alfalfa hay or pasture is fed, the remainder of the supplemental protein may best be supplied from an animal source, such as tankage or milk.

Extensive experiments in the use of pasture for hogs, and also in the use of all the farm-grown grains, separately and in various combinations as the basic feed, have been made. Experiments have been conducted to determine just how and to what extent oats and rye may be used to greatest advantage. Recommendations for their limited use have been made available. The by-products of the milling, packing, oil, and dairy industries have been under study to determine their usefulness as hog feeds. The practice of "hogging-down" corn, and of harvesting other standing field crops in like manner, has been found to be satisfactory and profitable.

Animal Breeding

As a result of the studies to develop methods for the selection and mating of hogs, to produce improvement in form and more efficiency in feed utilization, it has been demonstrated that selection may be based on rate of gain and the use of feed just as effectively as the selection of dairy cattle may be guided by milk records or of poultry by trap-nest records. A formula for basing selection of hogs on production records has been developed and is available.

It was found that a steer of essentially the same market grade and age as another may require 50 per cent more feed per pound of gain in body weight. The two most significant factors determining net profits on the individual animal were daily rate of gain and final market evaluation. They were essentially equal as indicators of net profit, and taken together they accounted for 87.3 per cent of the variations in net profits.

In the past the efficiency of beef cattle has been based entirely on body form. This study showed clearly that body form is important, but that the daily rate of gain is of equal importance.

Crossbred Swine Project

In a six-year study of crossbreeding swine, 1,535 pigs were farrowed of which 1,410 were farrowed alive, 1,134 were carried through the nursing period, and 848 were fed to market weight. Three different types of crossbreds were produced—first-cross pigs, the result of mating a purebred boar to purebred sows of another breed; three-breed-cross pigs, from mating first-cross sows to a boar of a third breed; and back-cross pigs, from mating crossbred sows back to a boar of one of the parental breeds used in making the first cross.

All three types of crossbreds were superior in several respects to the purebreds. More crossbreds were farrowed per litter, more were farrowed alive, and the pigs were larger at birth. The crossbred litters were larger at weaning and the pigs weighed more. The crossbreds gained faster in the feedlot and on less feed per pound of gain. They reached a market weight of 220 pounds in from 17 to 22 days earlier than the purebreds and on from 27 to 36 pounds less grain.

As a result of this study, a new method of breeding swine for market purposes is proposed. The method is called crisscrossing and it is carried out by alternating each generation in the use of boars of two different breeds.

Prenatal Development Studied

The important stages of development of sheep from the unfertilized egg to the fully developed lamb have been studied. All specimens have been photographed and measured while fresh, so the station now has a very complete record of normal prenatal development of the sheep. A similar study has been begun with cattle. The object of this work is to record the stages of normal prenatal development and then to take up a study of problems in heredity and reproduction from a fundamental method of approach.

DAIRY HUSBANDRY

The greatest contribution made to the dairy industry of the state was the standard for feeding dairy cows which resulted from experimental work by Prof. T. L. Haecker who became chief of the division in 1891. After 40 years this standard continues to be the basis for feeding millions of dairy cattle.

Under Professor Haecker's administration the station advocated the establishment of co-operative creameries in the state and he became known as the father of the co-operative creamery system. So successful were these co-operatives that the plan has been adopted throughout the

United States. Minnesota producer-owned and operated dairy processing plants came to be regarded as outstanding the country over.

Progress in Cattle Feeding

Minnesota's feeding system for dairy cattle was not the first. Others had been presented prior to 1900 but were little used under practical farm conditions. In tests to determine the nutrients required for milk production, results obtained by Haecker differed from those of earlier standards. This led him to continue his studies and after the completion of one of the most extensive experiments ever undertaken in animal nutrition he evolved an entirely new feeding method for milk production.

This method or standard was based on the new conception that the nutrient requirements for milk production are affected not only by the quantity of milk produced but by its quality, that is, the percentage of fat and other solids, as well. This principle has since been adopted in all recognized feeding standards. The Haecker feeding standard for dairy cows is used throughout the world. In its value to the dairy industry it ranks with the Babcock test.

Professor Haecker was especially adept in disseminating the knowledge gathered from his experimental work. He exerted an influence upon practical dairy feeding practices that was equal to or greater than that of any other man in this country.

Co-operative Creameries

In these early days dairy farmers produced butter so uneven in quality that no regular stable market for it could be expected. After a careful study of the possibilities of the co-operative creamery, as typified by a single plant at Clarks Grove in Freeborn county, Haecker became convinced that it was the forerunner of a system of dairy processing that would revolutionize the industry.

In the 10 years following the launching of his campaign the number of co-operative creameries increased from one to 542. With a record of 30 years of successful operation, these co-operative enterprises formed the foundation for what is probably the greatest butter marketing organization in the world, the Land O' Lakes Creameries that markets more than 85 million pounds of butter annually.

Minnesota has become the leading butter manufacturing state in the Union. It now manufactures more than 275 million pounds of butter in 846 creameries. It has 56 cheese factories having an annual output of about 11 million pounds. More than 34 million pounds of dry skimmilk and buttermilk are produced in the state annually, and nearly 27 million pounds of various types of condensed milk. Ice cream and casein manu-

facture have become stable industries. All this wonderful development can be traced largely to forces set in motion by the dairymen of this station.

To these major achievements Professor Haecker added experimental work in the selection and management of dairy cattle—the building up of herds; the discovery that calves could be raised on skim milk; studies of the nutrient value of feedstuffs, of beef production vs. dairy farming, and of the relation of the form of an animal to her producing ability and to economy of production. All these studies and many more aided materially in the development of dairying in state and nation and added millions of dollars to the income of America's farmers.

Research in Butter

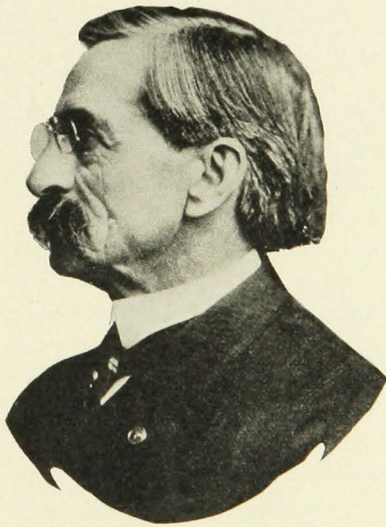
Problems concerning the manufacture of butter have been of two general types—those affecting the efficiency of creamery operation and those affecting the market qualities of butter.

Early investigation in co-operation with the Minnesota State Creamery of Albert Lea made it clear that butterfat losses in a creamery receiving cream for churning amounted to 1.4 per cent of the total butterfat handled. Later, what is known as the "Minnesota test" was introduced and gradually found its way into creameries in Minnesota and elsewhere. Methods were devised which have enabled creamerymen to hold fat losses in churning to a minimum.

During the days of the whole milk creamery it was a comparatively simple matter to sample the milk received. The composite milk sample was used by the butter factories then as it is used in the market milk plant, cheese factory, and condensory today. With the introduction of the farm separator and a change from the delivery of milk to the delivery of cream at the creameries, practical creamerymen applied composite sampling to cream. Study by the station dairymen of this practice revealed that the composite sample as taken in most Minnesota creameries is inaccurate in about 45 per cent of the deliveries made. It was further shown that the practice of dropping the 0.5 per cent reading in making the Babcock test was responsible for far greater errors than was the method used in preparing the sample.

In 1922 it was demonstrated that the average composition of butter made in the state contained slightly more than 82 per cent of butterfat and, what was of major importance, that a well-managed creamery might manufacture butter near 80.5 per cent of fat, thus making a great saving. The significance of the findings was soon realized by creamery organizations. In 1934 the Land O' Lakes Creameries handled between 85 to 90 million pounds of butter having an average fat content of 80.8 per cent.

As far back as the history of buttermaking goes, losses due to mold have been experienced. For many years the idea was current that moldy butter was the result of the condition of the refrigerators which were then generally cooled with ice. An investigation at the Minnesota Experiment Station completely changed the viewpoint regarding the source of mold infection, for it was made evident that molds find their way into butter largely as a result of improperly cleaned equipment. It was further shown that pasteurization of cream usually results in a product free from mold, and when mold is found growing on butter made from pasteurized cream it is a result of recontamination at the churn or from other equipment.



T. L. HAECKER

Came to the Experiment Station in 1891 and remained until 1918. Developed dairy feeding standards now in use throughout the world. Now professor emeritus in dairy and animal husbandry.

Marketing organizations, making use of these discoveries, have brought about greater progress in creamery sanitation in the short period of five years than had been accomplished at any time in the history of the industry in this state. A clean-up campaign was started which materially influenced the market qualities, particularly the keeping qualities, of Minnesota sweet-cream butter. In the words of an officer of one of the big companies, "the mold loss has been reduced 99 per cent."

Unsalted butter made from sweet cream sometimes has a cheesy flavor which has been traced to a combination of bacteria. The ob-

noxious flavors can be banished, it was proved, by general cleanliness, pasteurization, and the use of proper acidities.

Grading Cream

The work on cream grading serves to illustrate how a demand of the industry is foreseen and met on short notice. In 1934 the creamery industry started a drive to improve the quality of cream used for making butter. Work reported in the fall of 1934 showed how the methylene blue test might be applied in selecting high-grade cream. In addition, a method of making a sediment test on cream was reported. By January 1, 1935, supply houses in the northwest were selling the sediment test equipment to creameries of the state. A law passed by the recent legislature requires that the sediment tests be made by creameries at certain intervals on all cream received.

Achievements in Dairy Production

Feeding standards relating to the nutrient requirements for growth in dairy cows were of limited or doubtful value because of faulty derivation. Experiments were conducted by the late Dr. C. H. Eckles, successor to Professor Haecker, in which the nutrients required for growth were derived from the amount of nutrients actually required by a large number of animals while growing at a normal rate. The significance of this new standard is apparent when it is realized that about one-fifth of all dairy cows must be replaced each year by younger animals. The future value of these animals in the herd is determined largely by how they are fed during the period of growth.

The market value of whole milk is so high as practically to prohibit its use in calf feeding. Skimmilk feeding is likewise impracticable under these conditions. A plan was evolved at this station for weaning the calf from milk when only about 70 or 80 days old, with wholly satisfactory results in growth and development. Also, this station was the first to demonstrate that powdered skimmilk, powdered buttermilk, and semi-solid or condensed buttermilk may be used satisfactorily in raising calves.

That soybeans can be used with entire satisfaction in the dairy ration and with a saving in the cost of protein concentrates has been thoroly demonstrated. Satisfactory methods of including sugar beet tops in the livestock ration have been worked out and reported.

After allowing for all the skimmilk that can be used economically by feeding pigs, calves, and poultry in the state, a surplus of more than a billion pounds remains. Experiments showed that skimmilk can be used with excellent results as a protein supplement in the ration of

dairy cows and growing heifers, eight pounds of skimmilk replacing about one pound of linseed oilmeal.

Miscellaneous Achievements

The manufacture of foreign types of cheese is under investigation and already the possibility of ripening a Roquefort-like cheese in the sandstone caves along the banks of the Mississippi River has been demonstrated.



C. H. ECKLES

Came to the Experiment Station in 1918 as chief of the Division of Dairy Husbandry. Died in 1933 in the midst of active work for the promotion of the state's great dairy industry.

Dry milk studies have had a decided influence on the manner in which that product is packed and stored. A defect known as sandy ice cream has been traced to the crystallization of milk sugar, and suggestions made which obviated this difficulty. Methods of sampling and testing frozen cream without thawing have been worked out.

The dairy staff has carried a major rôle in the establishment of uniform methods of milk control in cities and villages by making available the results of research in sanitation and good dairy practice. This has meant a superior milk supply for the people of the state.

The maintenance of a dairy herd at the station has provided material for instruction and demonstration—a service that is difficult to estimate. Many of the best breeders got their inspiration directly or indirectly from the station herd.

Cow Testing Association Work

Since the beginning of co-operative cow testing in this state, a work supervised from headquarters at the station, 250,000 cows have been tested, 25,000 or 10 per cent of which have been disposed of as unprofitable. By eliminating the low producers and giving the remainder of the herds improved feeding and care, the average annual butterfat production of the 11,724 cows tested in 1934 was 308 pounds as compared to an average for all cows of the state of approximately 175 pounds.

Another activity of a similar nature in which the station has played a part is the advanced registry or "official" testing of purebred dairy cows. The advanced registry records kept under the supervision of the station have helped materially to establish Minnesota as one of the leading states for numbers and quality of purebred cattle.

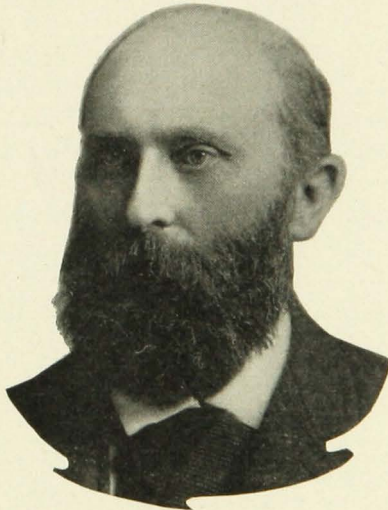
ENTOMOLOGY AND ECONOMIC ZOOLOGY

From the time of its first organization, the Minnesota Agricultural Experiment Station has served the people of the state by furnishing authoritative information regarding the control of insect pests of not only the farm, garden, and home, but also of the forests, elevators, mills, stores, and warehouses. An important part of its function consisted in testing the application of known methods of control under our local conditions and of trying out new or little-known methods. In addition to this constantly maintained service, the station has become recognized widely because of its research on problems of insect control.

The fundamental studies of the physiochemical principles involved in the proper spreading of spray mixtures on plants and of their adhesion to the leaves led to recommendations of great practical value to the orchardist. One of the many examples which might be cited is that of the discovery that the addition of soap to nicotine sulphate solution not only aided in liberating the nicotine but greatly increased the spreading power of the spraying. Even such theoretic studies as those of the positive and negative electric charges of leaves in nature prove to have an exceedingly important application in increasing the adhesive power of sprays. Possibly the most far-reaching in their practical application were the pioneer studies showing that the toxicity of a volatile organic compound is closely correlated with its volatility and that a decreasing volatility is accompanied by an increased toxicity. This has paved the way for some of the most important of recent advances in the development of efficient fumigants for grains and other stored products.

War on Insect Pests

As early as 1917, while the World War was at its height, the station investigators had already made experimental studies which showed that the dread "tear gas" chloropicrin was extremely toxic to insects. It is non-inflammable, and the fact that its irritating properties serve as a warning makes it less dangerous to human life than are some of the other much-used fumigants. Methods of its utilization in the fumigation of grains, of clothing, and of houses infested with carpet beetles and similar pests have been developed and are widely used.



OTTO M. LUGGER

Elected chief of the Divisions of Entomology and of Botany, Minnesota Experiment Station, in May, 1888, after service in the Bureau of Entomology, United States Department of Agriculture.

The extensive studies of the station on the control of insect pests of stored products has won wide recognition. These include critical studies of the relative toxicity of new or little-used fumigants, as well as of those in common use. It has been found that the efficiency of fumigants is very closely correlated with the temperature conditions under which they are used.

The rate of diffusion of a destructive gas in a bin or elevator of grain has also been determined as a basis for practical recommendations. The most significant point brought out in these experiments is that one fumigant may be best for one kind of insect, while against another apparently very similar insect better results are obtained by the use of a different gas.

Methods of Control Worked Out

One of the most important phases of the work in applied entomology in which the station has pioneered is that of emphasis on the importance of the ecological approach to the study of problems of insect pest control. Numerous fundamental researches on the relation of insects to such factors as heat, cold, and moisture have been conducted. These have furnished the basis for recommendations as to the necessary temperatures, either high or low, and as to the length of exposure necessary for killing various stages of different insects. They involve additional studies to determine exactly what ranges of heat or cold can be utilized without injury to the infested product or, if seeds, to their germination power. They furnish a basis for determining methods of control of various forest insects and of those infesting felled logs and lumber.

A striking illustration of the practical application of the principles underlying this work is afforded by the recent successful campaign against grasshoppers. Not only for grasshoppers, but for army worms, cutworms, and various other pests, the studies have made possible more efficient methods of utilizing poison baits. They have furnished authoritative answers to the very practical questions as to how long the eggs of certain very important parasitic worms of poultry and fur animals can remain alive and infective in the soil, in spite of changing seasonal conditions. In broader applications they, and the analysis of climatic factors, furnish the basis for predictions of insect outbreaks and for an estimate of the probabilities of geographic extensions of an insect pest.

Along a different line may be cited the fact that critical experiments on grain weevils have exploded the widely held belief that these insects are responsible for the poisoning of flour made from infested grain. Comprehensive studies on poisonous caterpillars conducted here are cited the world over for their bearing on medical entomology.

Animal Parasites

The study of a parasitic infection of honey bees and of its relation to the normal tissues has furnished a basis for important studies on diseases of these insects.

It has been demonstrated that dragon-fly larvae harbor a parasitic worm of hens and ducks which is responsible for a very serious disease of the ovaries. This has afforded an explanation for the almost complete cessation of egg laying in regions where the birds have free access to our lakeshores during early summer.

The station was among the first to call attention to the danger and initiate studies of the animal parasites of the silver fox and other fur-bearing animals in this country.

Too likely to be overlooked is the important service which has been rendered in the building up of library facilities and of a great reference collection of insects. This was begun by the first station entomologist, Dr. Otto Lugger, and has been constantly added to until it now furnishes an indispensable adjunct to the research work in economic entomology. It makes possible the accurate and prompt identification of newly introduced or unfamiliar pests, and it also gives service to schools and to the citizens of the state in general.

FORESTRY

Forest research and education were undertaken at the Minnesota station at the suggestion and insistence of President William Watts Folwell and Prof. Samuel B. Green. These men had no technical training in forestry—there was none to be had at that time in America—but Professor Green had studied the subject in his travels in Europe and soon after his return to the home station introduced several forestry courses and began a program of forest research.

In 1898 Professor Green published "Forestry in Minnesota," one of the first books printed in America on the subject of forestry. The book was used as a text in 14 or more agricultural colleges and in many normal and high schools and had a profound influence in stimulating interest in forest conservation.

"Prairie Forestry," the first bulletin of the kind from the station, reported the results of seven years of research to determine what trees were hardy, the best kind of mixed planting to use in order to secure the best soil cover, and the rate of growth of different trees. Thus, through its early research the station provided data for a reasonable and sound program for the planting of windbreaks and shelterbelts on the prairie farms of the state.

Cloquet Forest Station

The major investigational project is the management of the Cloquet Forest Station. For more than 25 years scientific forestry has been practiced on the 2,953 acres constituting the station. Large areas have been planted, thinnings have been made, and mature stands harvested, not only to determine the best methods to follow but also to increase production to the highest possible level.

A complete record is kept of every operation. When timber is harvested, detailed cost accounts are kept of felling, slash disposal, logging, and hauling. When an area is thinned or planted, cost records are kept of every operation. From these data a comprehensive plan of

forest management has been prepared. This state-owned forest is fairly representative of much of the forest land in northern Minnesota. Consequently, the private owner of timber land may study the yields of the forest, the cost of the different operations, and all other data at hand, and use the information in the management of his own holdings.

With the possible exception of the Yale and Harvard forests, there is probably no other timber land area managed on such an intensive basis as the Cloquet forest, and few if any states have made so thorough a practical demonstration of what can be done in forest management as has the State of Minnesota.

It has been demonstrated at the Cloquet station that the cheapest kind of planting stock, two-year-old seedlings, may be used successfully on the more open sites. Brushy sites require planting stock having better root development and larger tops in order to compete successfully with the brush. On such sites three- and four-year-old transplant stock is required. Cost of planting stock is, of course, an important consideration in making a financially profitable forest planting.

Planting methods have also received careful attention at the station. Nearly all the standard methods have been tried and complete records kept of costs and results. The station forest abounds with experimental plantations of all ages, from 1 to 25 years.

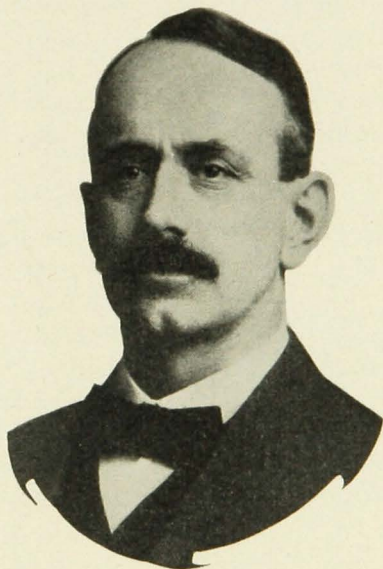
Other Practices and Studies

Forest crops are in a sense cultivated by removing some of the trees. Many of the experimental thinnings in the Cloquet forest are now in their fifteenth year. The supervisor of the Superior National Forest considered the experimental work at Cloquet of sufficient importance to justify him in sending all technical foremen of the CCC in his forest to Cloquet for a two-day training period.

Studies are made of timber yield and volume not only at Cloquet but elsewhere in the forest region. The solution of many problems in forest management can be found only by prolonged study of a series of permanent sample plots which include all of the available species and are located on different types of soils. Several of these plots at widely divergent points are being maintained.

Forest possibilities of cut-over land are also being given attention. Two counties, St. Louis and Lake, have been under survey. Forty-four per cent of the Lake County stands were found to be understocked. The surveys will be continued in other counties, for if the forest lands are to be made productive there must be an intimate understanding of forest conditions.

In co-operation with the federal Lake States Forest Experiment Station, studies have been made of the possibilities of aspen-producing lands, and, with the United States Forest Products Laboratory at Madison, Wisconsin, as a third co-operator, of the properties and utilization of aspen. The conclusion is that the bulk of the aspen crop will be marketed as a primary product rather than as lumber.



SAMUEL B. GREEN

Elected horticulturist of the Minnesota Experiment Station in April, 1888. Made dean of the College of Forestry in 1910, only a few weeks before his death.

Taxation and Land Economic Surveys

The important position which forest lands hold in the total taxable valuation of 12 of the 16 Minnesota cut-over counties, and the large area of such lands that on January, 1931, had been tax delinquent for a year or more, show that taxation of forest property in these counties has become a problem of major importance. The Division of Forestry has conducted a comprehensive survey of the whole question of taxation of forests in Minnesota, and suggestions have been made which should serve as a basis for the reconsideration of the forest taxation problem in the state. The division also co-operated with other divisions and the Minnesota State Department of Conservation in making a land economic survey. Money was provided for the study of but one county,

but as that county is representative of a much larger area the information gathered is of wide application.

Balsam fir is perhaps the most widely distributed and aggressive conifer in the Lake States. Unfortunately it is a short-lived species, being particularly subject to attack by fungi causing heartrot. The problem of determining the age to which it can be grown and not suffer severe losses has been studied in co-operation with the regional office, United States Forest Service. It was discovered that the tree can be grown rapidly to an age of 80 years before heartrot losses more than offset interest, and that in properly managed stands trees of the pulpwood size can be grown in 60 to 70 years. Heartrot should therefore not be as important in future stands as it is in the present wild stands.

Woodlot Crops

A study of the value and possibilities of the woodlots of southern Minnesota indicates that under adequate management they can produce an annual crop worth approximately \$2,500,000, probably three-fourths of which would represent wages of men and teams, and one-fourth, or about \$640,000, would be net profit in stumpage.

A survey has been made of lumber production and wood utilization in southeastern Minnesota. In 1927 approximately 171 million feet of lumber were used for industrial purposes in the region. Only 18.5 per cent of this total is produced within the state, the remainder being imported. Consumers do not use more home-grown material, it was found, because the supply does not meet the demand, and the hardwood lumber is not graded and is not properly sawed. These objections can be corrected, and as they are corrected a market will gradually be developed for most if not all the woodlot crops of the region.

HOME ECONOMICS

An enlarged program of research in home economics, dating from 1926 when the Purnell funds were provided by congress, has been developed by basing it upon the problems of the home and family life and co-ordinating it with teaching in the division. Outstanding phases of the work pertain to foods, nutrition, textiles and clothing, and home management.

Foods

A study has been made of the qualities of meat which affect its palatability and methods of cooking and utilization. Important factors contributing to quality are tenderness, juiciness, flavor, and aroma. An apparatus, the pressometer, has been developed for obtaining the "press

fluid" from heated muscle, and the method for studying the quality and quantity of this fluid or juiciness has been standardized. From the data obtained, it is apparent that about 11 per cent more press fluid is found in muscle heated to 58 degrees C. (136° F.) than in that heated to 75 degrees C. (167° F.). Chemical analysis of the press fluid showed that the moisture content varies directly with the interior temperature and that press fluid from the raw meat contains more total nitrogen.

These press fluid studies have been extended to include the general problem of the nature of the forces which hold the water in the muscle tissue. It was found that the muscle colloids "bound" a part of the water so that it should be considered as a part of the solid constituents of the muscle and not as simply liquid existing in a fluid, easily expressible state. Heat sufficient to coagulate the proteins releases a portion, but not all, of this "bound" water.

When research with foods was started in 1927 there were no standard methods for cooking meats. It was important, therefore, to develop methods for certain commonly used cuts. Methods of cooking pork roasts, cured ham, and bacon have been standardized as to the best interior and exterior temperatures and other exterior conditions. Methods for determining losses and for judging have been developed.

The general conclusion from a study of the canning quality of 24 varieties of Minnesota Fruit Breeding Farm strawberries was that a satisfactory berry for canning is of medium size, smooth and regular, rich red in color throughout, firm and juicy, with small seeds. Forty-two varieties of apples from the farm have been under test for determining the culinary quality and methods for judging. Methods have been standardized for baking, boiling, and mashing potatoes and score cards have been prepared for judging the cooked product. Experiments have shown that dry skimmilk can be used in any product in which liquid skimmilk is used.

Nutrition

Nutrition is one of the bases of life. We are still not in possession of many of the basic facts concerning this most important biological process. This division has been actively engaged in the study of some of the phases of this biological phenomenon. We have found in experiments on dogs that the different elements of the blood following hemorrhage are regenerated at various intervals. The replacement of the water in the blood plasma begins immediately, and it is completed within a short time, whereas the protein, calcium, and phosphorus fractions require several days to regain normal levels. The total volume of the red blood cells, the size and the diameter of the individual erythrocytes, and the amount of hemoglobin return to normal levels only with difficulty.

It has been found that the effect of the ultra violet ray lamp, now so commonly found in the home, has very little or no effect upon the hemoglobin, red and white blood cells, blood pressure, and pulse rate. It does seem to have some favorable effect in the prevention of colds.

The division, as well as other investigational units of this country, has been studying the basal metabolism of women. We have found that the metabolic rates of college women in Minnesota were higher than those reported elsewhere. Measured in terms of calories per unit of body surface, basal metabolism tended to increase as outdoor temperatures decreased.

Studies of the division staff have shown that the availability of calcium and phosphorus of both powdered and condensed milk was better than that of raw milk. The calcium of both raw and cooked carrots and of raw and cooked cabbage appeared to be well utilized by human adults.

Iron is one of the important requirements for growth. In order to obtain optimal storage, an allowance slightly above one-half that recommended for an adult man is necessary for children from 3 to 4½ years old. It has been found after careful study that better growth as measured by height and weight has been obtained in pre-school children whose diet was the most satisfactory, regardless of the season of the year in which the studies were made.

Textiles and Clothing—Home Management

Investigational work has had to do with the purchasing habits of consumers, with the commonly used ready-to-wear garments, the physical properties of fabrics, and silk weighting.

In 1926 plans were made for a qualitative and quantitative study of farm homes in Minnesota, with special emphasis upon the influence of the farm on the management of the home and the life of the family. The findings in this preliminary study showed the contribution of the farm to the income of the family, mostly in terms of food, both amount and kind, and of the different members of the family to the farm in terms of labor.

HORTICULTURE

Any discussion of achievements in horticulture at the Minnesota Agricultural Experiment Station should begin with a personal reference to Prof. Samuel B. Green, who came to the institution in 1888 and died in active service in 1910.

He was an outstanding educator and gave to his students in both horticulture and forestry courses of instruction which were not sur-

passed in other and older American universities. This led naturally to the organization of horticultural investigations, which, in turn, laid the foundation for the more extensive researches of recent years. He was the author of numerous bulletins and books that were of inestimable value in forwarding the development of fruit and vegetable growing industries in this state.

One of the last achievements of Professor Green, and possibly the most far reaching, was the establishment of the Fruit Breeding Farm near Zumbra Heights late in 1907. This branch station has produced a large number of hardy varieties of fruits. Minnesota is recognized as one of the leading states in the production of red raspberries. This high rank is attributable to the introduction of the "Latham" and "Chief," which were originated at the fruit breeding station. These varieties not only dominate the commercial industry in the state but are grown for home use in every county.

Two other varieties of small fruits, the Red Lake currant and the Como gooseberry, were originated at the breeding station and are the most popular of their kind in this state. Several varieties of strawberries have been produced, the more successful of which are the Minnesota, Minnehaha, Nokomis, and an everbearing variety, the Duluth.

Hardy Tree Fruits

In the breeding of hardy tree fruits the production of hybrid plums has been an outstanding achievement. Plums of eastern Asia were crossed successfully with some of the hardy native American species. Thousands of these hybrids have been produced and tested. Some individuals have combined the desirable characteristics of the parent species—large size, attractive color, high quality, winter-hardiness, productivity, etc. Such outstanding varieties as Underwood, La Crescent, Tonka, Redwing, Monitor, Superior, and Elliot, were introduced from these hybrids.

These plums, rivaling those of California, have displaced those formerly grown in the state except for a few trees of the older kinds that are kept as pollenizers for the improved types. Closely related to the plums are the dwarf plum-cherry hybrids resulting from a cross of the native sandcherry with various species of stone fruits. Nicollet and Zumbra are well-known varieties of this fruit.

The apple breeding work has been conducted on an extensive scale. More than 15,000 individual seedlings have been tested and many more are now under test. From this large group a goodly number of high promise have been selected and four have been named and introduced. Of the four, the Haralson has achieved outstanding success as a hardy,

red winter apple of good quality. Nurserymen say it is being planted more extensively in Minnesota than any other variety.

Other tree fruits of merit originated at the station are the Parker pear and the Flame crab. The former is a high-quality fruit adapted to the southern half of Minnesota, and the latter is a strikingly ornamental and culinary crab.

Produced primarily to meet Minnesota conditions, many of these fruits have proved valuable for other regions as well. The Latham raspberry is the leader in practically all raspberry-growing states east of the Rocky Mountains. A recent check of nursery catalogs from 38 states disclosed the fact that nurseries in 29 of them are selling one or more of the fruit varieties introduced by the Minnesota Experiment Station.

Fruit Culture

Technical studies associated with the fruit breeding work have resulted in the accumulation of a mass of fundamental scientific information. Studies of winter-hardiness based on field tests and special laboratory technics involving fruit plants have been carried on extensively for more than 20 years. The adaptation of fruit varieties to climatic conditions of the state has been the object of continuous study. Introduction of the hardy Russian varieties at an early date demonstrated that apples could be grown in this region.

A great deal of useful information has been obtained relative to plant behavior throughout the year. Respiration during dormancy, and the movement of food substances and water in the apple have been studied with respect to survival and yield. The pruning requirements of the apple, raspberry, and grape have been determined. Production costs have shown that apples can be produced efficiently in Minnesota.

Studies of the effect on market grades, of factors such as picking at different hours of the day, grading, rapid cooling, and refrigeration have enabled raspberry growers to improve the marketability of their product, extend their market time and area, and thus avoid losses that at times have been a serious handicap to the industry.

Truck Crops and Potatoes

Recent experimental work has supplied data on growth and respiration in the potato plant, fruiting habit in the squash, effects of ringing on growth and fruiting in the tomato, chemical composition of truck crops, storage of truck crops, use of mulch paper in vegetable production, and methods of supplying electric heat to hotbeds.

A study of the inheritance of string, fiber, width, and color of pod in beans furnished needed information regarding these characteristics

and led to the development of an entirely new type, a white-podded snap bean.

Muskmelon fields in a local market area were being destroyed by *Fusarium* wilt. Resistance to this disease, shown by test to be possessed by the Honey Dew and other Asiatic types, is being transferred to the Minnesota muskmelon.

Selection in inbred lines of Hubbard squash gave uniform and productive lines. This work led to the introduction of the Kitchenette and New Brighton varieties, and the supplying of true-breeding foundation seed of Table Queen squash to the growers.

The potato improvement work at the station has been one of its outstanding contributions. The group classification of potatoes published by Kohler in 1910 was adopted in all later classifications of the American potato varieties. Success in developing breeding material of merit by inbreeding and selection has stimulated interest throughout the country, and a large amount of foundation breeding stock has been supplied to breeders in other states and in foreign countries. Use of this stock for the production of superior varieties is progressing. The Warba variety, introduced in 1933, is extra early and a heavy producer. It is earlier than any named variety, which places it in a class by itself. In tests in the United States and Canada it has yielded better than the common early varieties and fully equal to the late main crop varieties. This rare combination of earliness and productiveness indicates what may be accomplished by modern plant breeding methods.

Ornamental Horticulture and Floriculture

Early in the history of the station the observation and testing of trees, shrubs, and flowers was begun with the idea of ascertaining what species and varieties were suitable for growing in Minnesota. Species were obtained from parts of the world having a climate similar to that of Minnesota, particularly from Russia and Siberia. From these countries came some of the species that have become important ornamental plants for this state such as the Siberian pea tree, *Caragana arborescens*, the Russian pea tree, *Caragana frutescens*, the Russian olive, *Eleagnus angustifolia*, the Tatarian maple, *Acer tatarica*, the Amm maple, *Acer gumala*, the Russian mulberry, a hardy variety of *Morus alba*, various varieties of the willow, *Salix vitellina*, particularly the weeping type *pendula*.

At the central station the original aim was to test out as many species as possible in an arboretum. At sub-stations many types were under test. Especially on the Coteau Farm in Lyon County, the emphasis was laid on ascertaining the relative hardiness of trees and shrubs

for ornamental plantings and for farm woodlots. This testing work has enabled the station horticulturists to recommend suitable ornamental plants for home and school grounds and public parks.

Not much breeding work has been attempted as yet by the ornamental section of the division. A little hybridization of lilies and some crossing work with chrysanthemums has been done. Several hardy types have been obtained. One of them, christened Hiawatha, is not only winter-hardy but has merit as a greenhouse chrysanthemum.

PLANT PATHOLOGY AND AGRICULTURAL BOTANY

Pioneer work has demonstrated the phenomenon of physiologic specialization among many fungi that cause plant diseases. Investigations show that many plant parasitic fungi comprise a large number of parasitic strains which differ greatly in their ability to attack different varieties of crop plants. Some of the most important of the fungi which have been investigated extensively in this manner are the stem rusts of wheat, barley, oats, and rye, and the crown rust of oats, corn rust, and sunflower rust. In addition, extensive work has been done on the existence of parasitic strains or physiologic forms in the smut fungi, including particularly the loose smuts of small grains, the stinking smut of wheat, covered smut of barley, intermediate smut of barley, smuts of sorghum, and corn smut.

A thoro investigation also has been made of physiologic specialization in the organisms causing the head blight or scab of wheat and barley, barley stripe, the fungi causing root rots, foot rots, spot blotch, and kernel discoloration of wheat and barley, and other organisms causing flax wilt and the pasmo disease of flax.

The results of these studies have assisted in explaining the vagaries in the development of plant disease epidemics, and the differences in resistance of varieties of diseases at different times and in different places, and have been valuable in the development of disease-resistant varieties of crop plants.

It has been shown definitely that new parasitic strains in fungi may be produced by mutation and hybridization, in fact, that different species and even different genera of plant disease fungi may hybridize and produce strains which are quite different in their parasitism from any previously known strains. Particularly has an attempt been made to ascertain the extent to which new strains were being produced in those groups of fungi that cause destructive diseases. The primary objective was to learn whether in breeding work it would be necessary to take into consideration the possibility that numerous new strains would be produced within a relatively short time.

Nature of Plant Disease Resistance

Investigations have been made of the nature of varietal resistance. It has been shown, for example, that the resistance of wheat to stem rust may be due to any one of three general factors or to some combination of them. A variety may be resistant because there is so much woody tissue in its stem that the rust cannot develop extensively, or it may be resistant because there are certain substances in the sap of the plant that make it impossible for the rust to develop, or, in some cases, the fungus is unable to enter the plant readily because of structural or behavioristic peculiarities of the variety.

Extensive studies have been made of the nature of resistance of flax to rust and of corn to smut. The causes for resistance of flax varieties to rust are essentially the same as those in the case of wheat. The resistance of corn is probably due to peculiarities of growth and certain structural elements. Similar experiments have been conducted to determine the nature of resistance of potatoes to scab.

Factors Affecting Development of Epidemics

In co-operation with the United States Department of Agriculture long-time experiments were made to find out why epidemics of stem rust developed in some years and not in others. There are two sources of rust in the spring wheat region—first, that which comes from barberry bushes early in the spring, and, second, that which is blown into the spring wheat region from the far south. These investigations made it clear that a final solution of the stem-rust problem required the eradication of the common barberry—first, because a large amount of rust is produced by it in the spring, and, second, because it is on the barberry that new parasitic strains of the stem-rust fungus are produced, and that those already in existence are enabled to persist better than they would without the presence of barberries. It was shown, however, that a certain amount of rust is blown in from the far south. This indicated the necessity of breeding for rust resistance as vigorously as possible.

Experiments also were made on the effect of meteorologic conditions, such as temperature, light, and moisture on the development of epidemics; on the effect of soil moisture and soil fertilization. It was shown conclusively that the application of large amounts of nitrogen was likely to favor the development of rust, whereas judicious application of phosphorous and potash was likely to reduce the amount of rust. These epidemiological studies of stem rust have cleared the way for proper emphasis on the different methods of control. Much work also has been done to determine the factors affecting the development of the

root and foot rots of cereals, the smuts of small grains, smuts of corn and sorghum, and other diseases such as barley stripe and flax wilt.

Development of Disease-Resistant Varieties

Since its establishment in 1908 the division has devoted many of its resources to investigations basic to the development of disease-resistant varieties. This work has naturally been done in close co-operation with agronomists and horticulturists. The breeding of disease-resistant varieties was first put on a sound basis at the Minnesota Agricultural Experiment Station. The work, therefore, can be considered pioneer work, particularly in view of the fact that a well-rounded program was undertaken.

Plant pathologists have co-operated actively with plant geneticists in producing disease-resistant varieties, including wilt-resistant varieties of flax, stem-rust-resistant varieties of wheat, spot-blotch-resistant varieties of barley, and resistance in corn to smut and root rots.

Control of Diseases

For many years field and laboratory experiments have been made on seed treatment with a view to devising more economical and effective methods of control. Many commercial preparations have been tested, and it has been possible to recommend to farmers the use of chemical dusts, many of which are far cheaper, more effective, and easier to use than the liquid fungicides which were in use formerly. An acid mercury dip for potatoes, not entirely original at Minnesota, was perfected to the point at which it is now being used in preference to the ordinary standard methods which were far more cumbersome and expensive.

Co-operative experiments with the United States Bureau of Plant Industry placed the barberry eradication campaign on a sound basis and led to the destruction of about one million barberries in this state, with consequent reduction in rust losses. Studies of the relation of the red cedar to apple rust in Minnesota made it possible to present sound recommendations for the eradication of the red cedars from the immediate vicinity of commercial orchards. Studies of the relation between buckthorn and crown rust of oats have shown that the rust-susceptible buckthorn should not be grown near fields of oats. Similar studies have been made on white pine blister rust and the associated host-providing gooseberry and currant bushes.

Increased Prices for Farm Crops

The division was instrumental in organizing a system of seed-potato certification which has provided a practical method of control of the destructive virus diseases and has provided also a source of high-quality seed stock for growers. A large seed-producing industry for Minnesota potato growers and great improvement in potato-growing methods have been brought about. Growers have obtained higher prices than ever before for seed stock.

The scab fungus makes barley unfit to feed to pigs and certain other farm animals. It was proved that much of the so-called "scab" was not scab at all, but was caused by fungi and bacteria which did not appreciably reduce the feeding value of barley. Farmers thus have received higher prices for barley that otherwise would have been penalized by heavy discounts on the market.

Insects in Relation to Plant Diseases

A co-operative project with the entomologists for investigation of the rôle of insects in the spread of plant diseases has produced such striking evidence of the close association of insects and plant pathogens that national and international interest in the subject has been greatly stimulated.

One of the outstanding results of practical value has been the elucidation of the potato blackleg disease problem. It was shown that the bacteria causing the disease were transmitted very largely by the seed-corn maggot. As a sequel of a thoro investigation of the disease, in which many important new facts were discovered, it has been possible to devise better control measures and to remove the blame for outbreaks of the disease from the seed grower, who previously had unjustly been held responsible.

The relation of bark beetles to blue stain of coniferous trees has also been studied, and some investigation has been made of the relation of insects and the rotting of logs and trees.

Control of Fruit Diseases

Much work has been done to control diseases of trees and small fruits more effectively and more cheaply than would otherwise have been possible. For example, it was shown that plum pocket can be controlled by spraying, whereas it was formerly believed that it could be controlled only by pruning and by the eradication of badly infected trees. Extensive experiments were made of the brown rot disease of plums, and many facts of basic importance were obtained. Spraying

schedules have made it possible for growers to control the disease as cheaply and as effectively as possible.

In co-operation with the Division of Entomology spraying experiments on apples have made it possible to recommend combined spray schedules which insure the control of pests as effectively as possible under Minnesota conditions. A contribution was made, in co-operation with other divisions, in enabling Minnesota growers to produce disease-free raspberries for sale within the state and to other states. The mosaic problem, insofar as it affected nurseries, was solved from a practical standpoint, and a method was devised for inexpensive and effective control of the powdery mildew of raspberries by clean digging in nurseries. Experiments are under way to devise simple and practical methods for controlling strawberry diseases. Comprehensive experiments are being made, in co-operation with the Division of Horticulture, with a view to developing superior disease-resistant varieties of small fruits and of tree fruits.

Forest Diseases

In co-operation with the station and government foresters, studies have been made of the rot of balsam fir, of root rots of pines, and of the epidemiology of white pine blister rust. From the study on balsam fir results were obtained which will make possible the use of cutting cycles and other practices which will reduce the losses from rot.

The studies on root rot of pines indicate that silvicultural practices probably can be used to reduce losses from this source. The studies on the epidemiology of white pine blister rust contribute to the use of effective and economical methods for its control.

A study, in co-operation with the Division of Forestry, of heartrot of aspen has made it possible to recommend silvicultural and cutting practices which will reduce losses. A study of aspen canker yielding results of practical value also has been made.

Investigation of the heartrot of many different kinds of trees has shown that there are different strains of the causal fungus and that some of them differ in their sensitiveness to chemicals used as wood preservers.

Seed Testing; Weed Identifying

The work of testing seeds for farmers and seedsmen was organized in 1906, and each year, in co-operation with the State Department of Agriculture, 8,000 to 15,000 samples of crop seeds have been tested for viability and for freedom from weed seeds. Research has been conducted as to causes of delayed germination and especially varietal differences in the seed dormancy of cereals. Treatments for breaking dormancy in certain hard-coated seeds have been devised.

Identification of weeds for farmers and the compilation of weed distribution maps of the state have been of value in developing plans for control in infested areas. From 1,000 to 2,000 samples of weeds have been identified each year for farmers. Seed and weed exhibits have been carried over the state on trains and maintained at county and state fairs. Prepared mounts of weeds and their seeds have been widely distributed.

Winterkilling

Early work in plant physiology dealt mainly with the winterkilling of crops. An artificial winter test for determining the hardiness of plants has been of value to horticulturists, agronomists, and plant breeders in selecting hardy varieties of plums, apples, cereals, and ornamental plants for growing in different parts of the state. The relation of the condition of nutrition and maturity of plants to winterkilling has been studied.

Study of the light relations of plants led to the successful use of artificial light in the growth of greenhouse seedlings and in the control of blooming by prolonging the length of the day. The light requirements for forest seedling growth has yielded data of value in determining the degree of cutting of timber stands to obtain desirable types of forest reproduction.

Fruit and Vegetable Ripening and Blanching

The process of treating fruits and vegetables with ethylene to ripen and blanch them was invented in 1924, and the patent was assigned to the University. Ripening of products is speeded by this method which is being used by jobbers in the United States and foreign countries. Recent work has shown that self-blanching celery varieties normally produce ethylene in the stalks. Evidently the mechanism of the natural process of blanching and ripening involves the production of ethylene-like substances.

Work on the frozen storage of fruits and vegetables has pointed the way for the storage of raspberries, muskmelons, rhubarb, pimentos, and other products in a frozen state to preserve their flavor. Also, work on the relation of types of wraps for fruits to prevent wastage has shown how to prevent the absorption of abnormal flavors and odors by fruits.

New Weed Eradicants

The introduction of new chemical weed eradicanats, ammonium sulfocyanate, ammonium persulfate, and others has opened up the possibility of the use of these and similar substances for killing weeds, barberries,

and shrubs. Their toxic action in the soil is comparatively brief and they introduce fertilizer elements, nitrogen and sulphur, after the action of the soil bacteria has converted them to nontoxic compounds.

POULTRY HUSBANDRY

Investigations in feeds and feeding have resulted in the development of formulas which have been adopted generally for starting and growing chicks, laying flocks, and turkey poults. Experiments during 1924-1926 demonstrated that liquid skimmilk or buttermilk could be fed as complete replacements for either starting or growing chick mash or for mashes for laying flocks with a saving of fully 50 per cent in the cost of production. This also proved to be a most simple method of feeding poultry profitably.

This division was one of the first, if not the first, to discover the benefit upon body development of a more liberal feeding of animal protein to growing chicks, demonstrating that what was apparently excessive feather development, and had been so considered commonly, was in reality subnormal development of the body which could be corrected by a more liberal supply of animal food. Bulletins descriptive of this discovery and details concerning this advanced method of feeding have been distributed on request to thousands of farmers of the state.

The division was also one of the first, if not the first, to formulate the "Point Five" or "Big Five" laying mash, which, because of the availability of its few components in equal weight amounts and its effectiveness for all classes and ages of fowls, has been widely adopted as a standard laying mash formula.

Turkey Production Revolutionized

Investigations in the nutrition of young turkey poults during 1925-1929 clearly pointed to the necessity of higher protein levels by about 50 per cent than were formerly thought necessary or commonly used. The protein levels suggested have been accepted by the leading commercial feed manufacturers and have become a definite part of the general practice in compounding mashes for turkey poults.

Experiments with turkey poults during these years demonstrated they could be raised very profitably in confinement. The necessity and importance of strict sanitation was recognized and established by the Veterinary Division working in co-operation with the Poultry Division. These experiments served to revive the turkey growing industry, which was then in decadence.

As early as 1915 the announcement was made that hens kept in con-

finement, having no outdoor runs, produced as many eggs as those having such runs. The statement was discredited generally at the time but has been accepted since, and this method of management has been adopted to some extent because it saves the expense of fencing and of care and sanitation of the outdoor runs.

Model Poultry House Popular

At a time when poultry raisers were having great difficulty in housing their flocks without experiencing heavy losses because their poultry houses were not properly insulated, ventilated, or lighted, this division designed and distributed a plan that met with instant popular approval and which has since become widely known as the Minnesota Model Poultry House. In all probability this house has been adopted more generally and is more widely used than any other state-designed poultry house for cold climates. Thousands of these plans have been distributed. Agricultural papers of nation-wide circulation have published the plans and recommended their use.

Strains have been developed of the most popular and practical varieties of fowls, including Barred and White Plymouth Rocks, White and Silver Wyandottes, Rhode Island Reds, and Single Comb White Leghorns, that have won many honors in competition at Chicago and top honors repeatedly at intervals for about fifteen years at the Minnesota State Fair for their prolificness as egg producers and high standard qualities. During these years breeding birds, especially males, bred at this station, were sought by breeders of Single Comb White Leghorns, Barred Plymouth Rocks, and Single Comb Rhode Island Reds for foundation stock.

SOILS

The qualities of the various kinds of soils found in different parts of the state have been determined so that field experiments can be located intelligently and the proper soil treatments recommended.

Minnesota has an exceptionally wide range in soils, many of them having some outstanding weakness, which, in most instances, may be corrected without undue expense. Field investigations have shown that the well-drained black prairie soils of western and southern counties tend to be low in available phosphate, and that the naturally poorly-drained dark soils of southeastern counties are low in potash as well as phosphate.

Acid soils in some districts have been found to respond to liming for alfalfa and sweet clover, while in other districts equally acid soils do not need liming for these crops. In most districts the peat soils

require applications of both phosphate and potash, but in northwestern Minnesota only phosphate is needed. On most Minnesota peat bogs liming is without benefit, but on some all farm crops fail unless lime is first applied. Many of the sandy areas commonly regarded as having the poorest soil are well adapted to alfalfa if given the particular management or treatment required.

Soil maps have been made of about 30 per cent of the total area of the state. This mapping, or soil surveying, has been done in cooperation with the Bureau of Chemistry and Soils of the United States Department of Agriculture, which has borne the cost of printing the colored maps and publishing the reports. Soils have been mapped in 25 counties and parts of 10 others. In the surveyed areas 275 different soil types have been recognized, and their distribution is shown on the maps. These are being graded according to their suitability for different farm crops.

Soil Requirements

The black and brown prairie soils are rich in lime, nitrogen, and available potash, but on a large proportion of the fields profitable crop increases are caused by the application of a phosphate fertilizer. On the lighter-colored soils of southeastern counties, which are more poorly supplied with nitrogen and lime, it has been found that nitrogen fertilizers increase crop yields and that legumes are important for the maintenance of the nitrogen supply. Many of the fields need liming for alfalfa or sweet clover, altho not for the common clovers.

On the heavier soils of the northeast, with its naturally forested counties, nitrogen has been found to be the commonly deficient plant nutrient. Sands and peats show greater variations in their requirements. Information gained as to the specific needs of the various soils of the state has made it possible to avoid the extensive use or trial of fertilizer constituents or of lime for crops on which they are likely to show little or no benefit.

In the greater part of the state the surface soils, and also the sub-soil to a greater or less degree, are acid in reaction. Neutral soils require no application of lime. It has been shown that in few places, except on the low-lime peats, do farm crops other than alfalfa and sweet clover show a benefit from liming. Even for these two crops a need for liming is limited to the extreme southeastern counties and to parts of the sandy areas in central and northeastern counties. Altho the heavier soils in the latter area are just as acid in reaction, the use of liming materials in but few places increases the yields of alfalfa hay.

An area in the north central part of the state contains many fields on which yields of clovers, and especially of alfalfa, can be greatly in-

creased by the application of sulphur fertilizers, such as sulphur flour or gypsum, while in the remainder of the state no evidence of sulphur deficiency has been found. The deficiency in the limited northern area is to be attributed to the very low sulphur content of the rain and snow falling there rather than to an unusually low sulphur content of the soils. A method of recognizing the sulphur-deficient fields by chemical analysis of the crops has been developed. The field work on the subject has been centered at the Bemidji experimental fields. As a result of this discovery, in the township in which these fields are located, alfalfa, the greatest sulphur-demanding crop, is now grown on almost every farm and occupies a greater acreage than any other crop.

Improvement of Sandy Soils

Minnesota's area of sandy soils probably exceeds five million acres on which 7,000 families are entirely dependent for their living. These soils are drouthy and under cultivation ordinarily decline very rapidly in productivity, due to exhaustion of the limited natural supply of nitrogen and to the difficulty of securing stands of the clovers and to the low average yields even when stands are secured. While a considerable part of these soils must be regarded as submarginal, under intelligent management and the use of methods developed by the experiment station, a large portion can be made productive without great expense, and its continued operation as farm land appears quite justifiable. Under the older and ordinary methods of handling these light soils, probably all of them would have to be considered submarginal, even under pre-war price conditions.

A large part of these sandy soils is well adapted to the successful production of alfalfa, provided the growers follow the methods developed on the various sand experimental fields typical of the sandy soils from the Twin Cities to the Canadian border. In some places an application of lime or marl is required; in others, potash, and on one large area only sulphur. Fair yields of non-legume crops may be obtained following the alfalfa and also on the fields fertilized with the manure resulting from the feeding of the hay. Sweet clover, which is not so well adapted to these soils and in general is not so profitable, still has a definite place on sandy farms and requires the same soil management and treatment as alfalfa.

Utilization of Peat Soils

Minnesota has about seven million acres of peat soils. The larger part, in northern counties, is located where agricultural development is not to be encouraged at present, but there are tracts of it on many thou-

sands of well-developed farms. Previous to the extensive research at this station and the maintenance of experimental fields on peats of different character, there were only a few acres under successful cultivation, and these were adjacent to abundant supplies of stable manure. At the present time thousands of Minnesota farmers are making profitable use of their peat bogs for hay, pasture, hardy vegetable crops, and in parts of the southern half of the state, for potatoes. Before going to any expense for drainage, breaking, and fertilization, a farmer can learn from this experiment station what crops his peat bog can be adapted to, what measures are necessary for this purpose, and their approximate cost.

Reed canary grass, a forage crop which has been a subject of much interest in this state since 1927, has been conspicuous in the trials on the peat experimental fields, both high-lime and low-lime, to determine its requirements of the various fertilizers as well as of lime, the influence of the depth of the watertable and of seedbed preparation upon yields, and its resistance to winter injury as affected by soil character and soil treatment. It has been found a very valuable crop for peat soils that are sufficiently well drained, while still exceptionally well supplied with water, when both phosphate and potash, and at times also nitrogen, are liberally supplied.

Marl Deposits

In 1921, when only two or three deposits of marl were known in Minnesota, the legislature made a small appropriation for a study of the value of marl (a form of lime) for agricultural purposes. Hundreds of marl beds were soon located. Samples were analyzed and the material tried out on the experimental fields on sand, low-lime peat, and lime-deficient heavy soils. At many widely scattered points marl was excavated and given to near-by farmers to try out on their fields. The marl beds are found chiefly in the vicinity of sandy soils, where they can be used to advantage on lime-deficient soils in preparation for alfalfa and sweet clover.

Soil Moisture and Soil Drifting

Studies of the moisture content of the soil and subsoil have been carried on for a long period, including some of the wettest seasons and the drouth of 1934, and dealing with a wide range of soil types—from clays to deep sand. These studies have shown to what extent available soil moisture may be stored in the subsoil and how low it may later be reduced by crops, as well as how much may be carried through prolonged drouths. Alfalfa is the only common crop that is able to draw

upon the moisture in the deeper subsoil, and on many soils even the roots of this crop are limited to the surface three or four feet because of defects in the subsoil, either a gravel layer or an indurated horizon. The rise of water from the watertable to within reach of crop roots is, in most parts of the state, too slight to be of importance during periods of drouth or at any other time.

On the light sandy soils drifting is experienced nearly every year unless special precautions are taken. Control of drifting has been one of the objects of the work on the sand experimental fields from the time of their establishment. Methods for largely controlling it have been worked out. On the heavy soils drifting occurs only rarely and then in exceptionally dry and windy seasons, such as 1934. On these soils similar methods are effective and can be applied with less departure from the present common practices.

Forest Floor and Agriculture

Studies have been made of the forest floor (litter and leafmold) of pine and hardwood forests to determine the weight per acre, and the reaction and the chemical composition as well as the relation of these to the chemical composition of the leaves of the more important forest trees. The intensely acid forest floor common in northern European coniferous forests, known as "raw humus," was not found. Field experiments have shown that the most acid forest floor so far found in Minnesota may be incorporated with the soil without any deleterious effect, even on our most lime-demanding crops, alfalfa and sweet clover.

The experiments have also shown that the complete destruction by fire of the forest floor, in advance of breaking, similar to what results from an extremely severe forest fire, does not lower the yields of the succeeding crops of alfalfa or sweet clover, nor of non-legume crops when grown in a short rotation that includes clover or alfalfa.

In parts of the southeastern counties erosion of the surface soil has reduced productivity. The experiment station has worked out inexpensive methods for the rehabilitation of such eroded areas where there has not been severe gullying.

VETERINARY MEDICINE

The Division of Veterinary Medicine was established in 1888. In the 47 years that have elapsed the staff has studied diseases of farm animals. This was the intent of the founders who fully realized that a successful livestock industry depends in part upon the control and eradication of diseases.

Bovine tuberculosis received the attention of the veterinary staff many years ago. The efficacy of the tuberculin test was studied here, with results that helped to establish the fact that it could be used to find infected animals in a herd. The late Dr. M. H. Reynolds, who for many years was in charge of the division, took an active part in this work and helped to formulate and develop the policies of the Minnesota Livestock Sanitary Board with which the station veterinarians have always co-operated to the fullest extent.

The results obtained with the tuberculin test here and elsewhere prompted the formulation of a plan whereby herds that had been tested and found free of tuberculosis could be officially accredited as such. The plan was adopted by the State Sanitary Board and also, with some modifications, by the federal government as the most satisfactory method of giving official recognition to herds that were free from this disorder. In 1922 the government increased the accredited unit from the basis of a herd to the basis of a county. This became known as the area plan of tuberculosis eradication and by means of it all Minnesota cattle have been tuberculin tested and our state is now officially recognized as an accredited tuberculosis-free area.

Control of Bang's Disease

Bang's disease, erroneously called contagious abortion, affects cattle, goats, and swine. It is a disease of great economic importance. Because of the close relationship between it and undulant fever in the human family, it commands attention from the public health standpoint. Research on this disease has been in progress for several years and the objective, to a large extent, has been attained. Progress is attributed to the fact that a test can be made with the blood serum of the animal which will show whether or not it is infected by the causative organism, *Brucella abortus*. Studies in the laboratories here have contributed materially to the application and standardization of the test. It has been shown that by the systematic application of the agglutination test and the removal, segregation, or slaughter of all reacting cattle, and reasonable attention to the principles of herd hygiene, a herd can be freed and kept free from Bang's disease.

Vaccination experiments with Bang's disease proved that the value of immunizing agents was slight. Many bacteriological examinations of the milk of infected animals indicated that approximately 75 per cent shed *Br. abortus* into the milk at one time or another and that about 35 per cent of the infected cows are chronic carriers of the organism in their udders.

Investigations of Bang's disease placed the division in position to

be of great service to cattle owners of the state who sought aid through the cattle reduction program conducted by authority of the Agricultural Adjustment Act. From August, 1934, when this work was begun, to April 15, 1935, more than 350,000 agglutination tests for Bang's disease were made in this division.

Sterility Studied

Much attention has been given to the diseases of the reproductive organs of farm animals. Studies prove that by proper treatment animals that seem to be incurably sterile can often be returned to a normal reproductive status. It is of course equally important to know when it is more profitable to remove a sterile animal from the breeding herd. In many cases, from the standpoint of the breeder, it is important to know at an early date whether or not an animal is pregnant. Investigations conducted here show that pregnancy can be determined as early as 35 to 40 days after conception.

Algal Poisoning

More than 40 years ago there occurred a rather mysterious and fatal disease in a group of cattle that drank water from a lake in the southern part of the state. An investigation indicated that the trouble resulted from the ingestion of a form of plant life (algae) that was found to be growing in the water. In the last decade similar outbreaks have occurred among cattle and sheep that drank from other lakes. In every instance algae have been found in abundance. Our studies have demonstrated that certain algae under certain conditions form and liberate poisonous substances which cause sickness and death of animals. This finding is extremely significant in its public health aspect.

Sudan Grass Findings

The drouth of the last few years has stimulated great interest in drouth-resistant plants. One of these, Sudan grass, is a potential source of hydrocyanic acid. Because of the extremely lethal properties of this substance, studies of such poisoning are in progress. Thus far the work shows that when very small quantities of hydrocyanic acid are deposited in the blood stream death soon results. On the other hand, when relatively small quantities are ingested by mouth harmful effects may or may not follow. Of greater significance, however, is the fact that thus far all attempts have failed under experimental conditions to produce symptoms of hydrocyanic acid intoxication by the feeding of Sudan grass that was grown, stored, and handled under various conditions. This is in marked contrast to several field cases where it is suspected

that the sickness and death followed the ingestion of cyanogenic plants. Considerable success has been obtained with antidotal preparations used on experimentally induced cases of hydrocyanic acid poisoning. These studies are in co-operation with the Division of Agricultural Biochemistry.

Ventilation Studies

Ventilation of stables, the objective being to determine the least amount of air change necessary to maintain the normal health and comfort of farm animals, has been studied sufficiently to warrant the conclusion that cattle can be kept in unventilated stables for relatively long periods (37 days) without particular injury. The atmosphere in the specially constructed stalls contained sometimes as much as 2.67 per cent of carbon dioxide. Animals, it appeared, adapt themselves to atmospheric changes if the changes occur gradually. Sudden changes should be avoided.

Diseases of Swine

When in 1907 the Bureau of Animal Industry announced the discovery of a promising preventive treatment for cholera, a dread disease of swine, staff men of this division familiarized themselves with all facts concerning the treatment. In 1908 hog cholera anti-serum and hog cholera virus were produced in the laboratories of this division for the purpose of experimentation and demonstration. As a result, it devolved largely upon the veterinary staff to convince Minnesota swine growers of the value of these products. Meetings and demonstrations were held in many parts of the state. Later it became the duty of the division to produce hog cholera anti-serum and hog cholera virus on a large scale and distribute it for use in the state. From 1910 to 1918 approximately 100,000 doses of serum and virus were produced and distributed.

The death of many suckling pigs was found to have been caused by anemia, a lack of red pigment in the blood, and that this disease did not appear when the pigs of three to five days of age had opportunity to eat earth. This showed that the disease bears some relation to the chemical elements contained in the soil, and that the most likely of them is iron. It has been suggested that earth should be placed in the farrowing pens so that little pigs may have access to it.

Work for Healthy Poultry

Nothing definite was known as to the transmission of avian tuberculosis through the egg until an investigation was made by this division. The results revealed that such transmission can occur altho it does not do so frequently.

The economic importance of hatching and raising chicks from pullorum-disease-free flocks has been emphasized by research work. The agglutination test proved to be of great value in the detection of infected adult poultry, and its use is advocated. In its acute form pullorum disease causes the death of many baby chicks. It sometimes occurs as an acute disease in older birds, but more often a chronic form affects the adult bird. It was shown that when penned together chronic carriers of the disease will transmit the infection to susceptible adult birds.

At the present time an investigation is being made of a disease of poultry, known by the term leukemia, that has become widespread in this state and other states. Studies thus far indicate that the disease may be inherited.

In co-operation with the State Livestock Sanitary Board the division maintains a laboratory for making diagnoses of diseases of animals. Infectious diseases are detected and studied. Much valuable material is thus gathered by members of the staff for use in their investigational work.

PUBLICATIONS

The Division of Publications was organized in 1916 to bring under one unit all the allied publicational activities relating to agriculture. For several years previous an Office of Publications had been maintained under the supervision of an "editor," as the individual in charge was known.

Thereafter the work of the division developed rapidly, taking on, in addition to the editing and distribution of bulletins and educational press material, publicity for the Experiment Station, for the College and School, the Division of Agricultural Extension, and the University as a whole. These multiple activities have become so intermingled that it is now difficult to separate the division's achievements in the Experiment Station from other activities.

The outstanding achievement of the division has been that of enlisting co-operation of the press of the state in the spread of useful agricultural information to the entire public. This has included the publication, in news form, of the results of experimentation; the announcement of improved practices in agriculture, forestry, and home economics, and the printing of information concerning the work of all divisions at University Farm and the branch stations. This co-operation by the press has been brought about by a variety of means, the setting up of which in each case has been an achievement in itself. An achievement of major importance to the Experiment Station has been an im-

provement in the presentation of experimental results in bulletin form and the betterment of methods and economies of distribution. The old custom of sending bulletins to large numbers of persons on fixed or expanding mailing lists was abandoned and the practice of sending bulletins only to those requesting them was substituted. This meant the maintenance of a mailing list of those wishing to be informed of the publication of new bulletins and the sending out at regular intervals of notices of new publications; also the preparation and distribution of announcements of new bulletins, through the press and radio. This practice has reduced waste in distribution, and funds so conserved have permitted the publication of larger numbers of bulletins.

Experiment Station Publications

This division has supervised the editing, printing, and distribution of 621 bulletins. In 1915-16 about 450,000 copies of bulletins of all sorts were distributed, 280,000 on fixed mailing lists and 170,000 in answer to special requests. In 1934, 603,426 copies were distributed in response to special requests.

A summary for the Central Experiment Station follows:

Annual reports	41
General Series Bulletins	315
Technical Bulletins	104
Press Bulletins, issued to supply information called for by some emergency (now discontinued)	44
Journal Series Reports,* papers prepared for publication in scientific and other journals, reporting progress in research.....	1,350
Class Bulletins (now discontinued).....	15

* Record kept only from July 1914 to date.

Since the beginning, radio broadcasting in Minnesota has been used as an effective medium of getting Experiment Station results to the people.

The present admirably equipped and efficient University Printing Department is an outgrowth of the activities of the Division of Publications. The printing plant now does practically all the University's printing, amounting to more than \$100,000 annually, at a very considerable saving in expense. For the Experiment Station, as well as for the other departments, this means the publication of larger numbers of bulletins than could be provided otherwise and the more expeditious printing of reports of experimental work. It means fewer delays in getting Experiment Station results to the farmers who can make practical application of them.

Emergency Publicity

During the World War, especially after the entry of the United States, when the federal government was calling on the states to expand and intensify production, the Division of Publications increased its efforts to enlist the co-operation of, and to give service to, the press. To these extra duties were added those of supervising the publicity of the Minnesota food administrator's office, at the head of which was the director of Agricultural Extension.

The Agricultural Adjustment Administration and the Minnesota administrator of the Adjustment Act, gave this division added duties. It supervised the preparation and distribution of all state material, and, at the same time, looked after the distribution in Minnesota of material coming from the Washington office of the AAA. This division also supervised the publicity program of the Drouth Emergency Relief Administration in Minnesota.

In all of these emergencies, the Experiment Station has been concerned. Each placed on the station extraordinary duties, calling for co-operation on the part of farmers and the rest of the public. The Experiment Station has been able to reach the public at all times through its Division of Publications.

THE GRADUATE SCHOOL

Close relations exist between the station and the research work which graduate students in agricultural subjects present as theses for advanced degrees in the Graduate School. In most instances these theses are a part of some one of the numerous Agricultural Experiment Station projects and the adviser of the graduate student forwards the work of the station and at the same time trains the student in research technics by assigning to him some phase of an Experiment Station project, and supervising his work.

The Graduate School was formally organized in 1914. Prior to that time only occasional students were granted advanced degrees in agricultural subjects, only 30 Master of Science degrees and 3 Doctor of Philosophy degrees having been granted prior to 1914. Since 1914 there has been an enormous increase in graduate work at the University of Minnesota so that at the close of the June 1934 commencement 640 students had been granted the Master's degree and 263 had been granted the degree of Doctor of Philosophy in agricultural subjects. Approximately one-fourth of all the Master's degrees and approximately one-third of all the Doctor of Philosophy degrees which have been granted by the University of Minnesota have been in the field of agriculture.

Foreign students in very considerable numbers have been attracted to the agricultural department of the University, and 59 have received the Master's degree and 49 the Doctor's degree. Most of them have returned to their homeland where they have practiced technics with which they became acquainted in the laboratories of the Minnesota Agricultural Experiment Station, thus contributing an international influence.

In January, 1934, a study was made of the present occupation of 654 individuals who had received advanced degrees (428 M.S., 226 Ph.D.) in agriculture at the University of Minnesota. Approximately one-third (216) were teaching in colleges or universities, in most instances in agricultural institutions. Of these teachers 57 held the rank of professor, 37 the rank of associate professor, and 62 the rank of assistant professor. Twenty-eight were heads of their subject matter departments.

Another large group, approximately one-fourth (169) of the 654 individuals, were in the service of the federal government or in various state non-teaching positions, in most instances in agricultural experiment stations. In addition, 51 more were in similar positions in the service of foreign governments. Of the entire group of 654 it was found that 453 were either teaching in colleges or universities or were in government service, and nearly all of the remainder were definitely engaged in some occupation directly related to agriculture. Only 18, or 2.7 per cent, were definitely classified as being in a non-agricultural field of activity.

Thus the Minnesota Agricultural Experiment Station has trained workers in agriculture for every state of the Union and for 16 different foreign countries. This wide dissemination of research ideas and agricultural technics must be recognized as one of the outstanding achievements of the station.

THE NORTHWEST BRANCH

Emphasis has been placed largely upon the solution of regional problems relating to the production of field crops; the maintenance of soil fertility; the establishment and maintenance of windbreaks, ornamental shrubs, flowers, and fruit trees; the production of bush and small fruits, potatoes, sugar beets, and garden vegetables, and the breeding and feeding of livestock and poultry.

Farm Crops

Sweet clover has been studied from the standpoint of varieties and species, cultural methods, soil improvement, weed control, and its use

as pasture and hay. The common white biennial (Bokhara) has proved the most satisfactory for general use in the region. Wheat has been more satisfactory as a companion crop than oats, barley, or flax. No other pasture crop or pasture mixture has proved so dependable and high in carrying capacity as sweet clover. These studies have been responsible in a large measure for the wide use of this crop in the Red River Valley.

Eradication studies of perennial sow thistle have shown that sodium chlorate can be used efficiently only on small areas, and that effective control can be obtained by early plowing, use of sweet clover and alfalfa, and bare fallow.

Wheat, oats, and barley grown continuously yielded practically the same as when rotated with each other. Gopher and Anthony oats, and Mindum wheat, bred at the central station, and the Crookston strain of Northwestern Dent corn, selected at the branch station, have been increased and distributed to farmers by the station and are now commonly grown in northwestern Minnesota. More than 30,000 bushels of registered seed of recommended varieties were produced for foundation seed from 1921 to 1934, inclusive.

Horticulture

Tree and shrub plantings of many varieties and species, as well as seedlings, have been an important phase of the station activities. Extensive trials have been made with tree, bush, and cane fruits to determine winter-hardiness, general adaptation, and the more desirable methods of culture. Only fruits possessing a high degree of winter-hardiness are recommended for the valley. Studies with garden crops have aided materially in finding the better varieties and methods of handling.

Many phases of potato growing, including choice of varieties, cultural practices, disease control, and fertilization, have been studied, and results have aided in developing correct methods for the use of farmers. The station co-operates in the state and nation-wide potato-breeding project.

Animal Husbandry

Feeding trials have been conducted with beef cattle with the result that the more desirable roughages and concentrates common to the region have been determined. Sweet clover hay has been used extensively, it having been demonstrated in trials that as a roughage for wintering yearling steers it was equal to alfalfa when these roughages were fed with corn silage and oat straw. Ground barley was found to be about equal to shelled corn for baby beef calves, while oats proved

somewhat less satisfactory. Wheat proved the equal of barley, while rye was somewhat unpalatable.

Crossbreeding of swine, carried on for several years, showed cross-bred pigs to be somewhat heavier at birth and to make more economical gains than purebreds. Purebred animals must be maintained and the crosses used for market pigs only. Success depends upon the use of good purebred foundation stock.

Dairy Husbandry

In 1932 and 1933 a pasture study was conducted with cows in milk to compare sweet-clover pasture with a pasture consisting of a mixture of quackgrass and bluegrass. The cows on sweet clover did not maintain their body weight as well as those on the grass pasture, but their milk was of superior quality. Total digestible nutrients per acre of sweet clover were 2,934 pounds in 1932 and 1,605 pounds in 1933; on grass, 941 pounds in 1932 and 832 pounds in 1933.

Sheep Husbandry

The question of size of ewes for market lamb production was studied in the fall of 1933. Two groups of grade ewes were used, one possessing large size and the other composed of fine-boned ewes of medium size. The large type produced a 184 per cent lamb crop at birth; the medium type, 154 per cent lambs.

Poultry Husbandry

Emphasis has been placed on pedigree trap-nesting and feeding trials with laying hens and growing chicks. As a result of consistent trap-nesting records and rigid selection, the average production of the station flock was increased from 144 eggs per hen in 1922-23 to an average of 221 eggs in 1933-34. Many hens in the flock have produced more than 300 eggs a year, the highest record being 321 eggs.

Wheat and barley proved to be the most efficient grain combination from the standpoint of egg production. Cod liver oil added to a standard ration resulted in an increase of 6 per cent in egg production, 14 per cent in fertility, and 19 per cent in hatchability. The trials indicated that the custom of fasting chicks from two to three days after hatching should be discontinued.

NORTH CENTRAL BRANCH

At the outset this was a forest experiment station, with Warren W. Pendergast as the first superintendent. He was killed in an accident soon after starting work, and H. H. Chapman was appointed his successor. Trees were planted under Mr. Chapman's supervision on land

not suited for farming, the agricultural land being used to determine what crops and varieties were best adapted to the soil and climate of this region.

In March, 1904, A. J. McGuire became superintendent, and the work of dairy development was begun. The type of agriculture now followed in the region is largely due to his teachings. He can rightly be called the "father of dairying" in northeastern Minnesota.

Progress in Dairying

The station's dairy herd, the foundations of which were laid by Mr. McGuire and developed by Otto I. Bergh who followed him as superintendent, attracted wide attention for many years by reason of its steadily increasing production records. Herd improvement began when purebred Guernsey bulls were purchased. Later purebred Guernsey heifers were added, and nearly all the females in the present herd are their direct descendants. There are now about 55 cows in the station's dairy, 30 of which are milking animals and the remainder young cattle and herd sires. Some 30 head are purebreds; the others, high grades from the old foundation cows. The herd has been used from an early day in experimental trials and has supplied many breeders with foundation stock.

Farm Crops

Fertilizers of various kinds have been under test many years. For seven years potatoes returned an average yield of 272 bushels an acre when 10 tons of manure were applied once every three years. Where no manure was applied, the cultural treatments being the same as for the fertilized plots, the average yield was only 100 bushels an acre.

Commercial fertilizers have been tested alone and in combination on potatoes, oats, and clover in rotation. Best results were obtained from potash.

Grimm alfalfa, sweet clover, alsike clover, and reed canary grass have proven valuable for the region. Silage and ear-corn projects have greatly assisted dairy farmers in this region. Many varieties, strains, and crosses of oats, barley, spring and winter wheat, field peas, and flax have been studied in the small grain tests, and seed of the best varieties has been increased and distributed among the farmers.

Horticulture

That small fruits can be grown in this northern area has been demonstrated. Raspberries have proved a real success, and plums and the sand cherry hybrids do well, but of the apples, only the hardy crabs are considered promising.

Trials with potatoes have been extended to include seed certification and the tuber and hill system of planting. Hundreds of new crosses have been grown in an attempt to discover better varieties. The station has played an important part in distributing seed of the Warba, a new early, high-yielding potato.

Forestry

About 100 acres were set aside at an early day as forest reserve. Many fine old pines remain, and natural reproduction is making a good showing. Besides the natural seedlings, some 40,000 trees, mostly Norway pines, have been planted.

Livestock

A Duroc-Jersey swine herd is under development and will supply good breeding animals for northern farmers, many of whom have become interested in this breed. Most of the lambs from the station flock are sold for breeding purposes. Four-H club members buy them as foundation for purebred flocks or for exhibition purposes. A large number of mares are being mated with station stallions to aid the farmers in solving their farm power problems.

WEST CENTRAL BRANCH

Soils and Crops

Long-time experiments have shown that the clarion silt loam typical of this area is deficient in phosphorus, and the use of phosphate fertilizers has produced increased yields of the various crops. Farmers have been saved time and money by the discovery that west central soils do not need lime to grow alfalfa successfully.

A project begun in 1916 and carried on for 12 years demonstrated that yields of corn and wheat are only slightly increased by the application of either straw or stover as a fertilizer. Results have seemed to indicate that it is not profitable to plow under clover as a green manure crop in this region.

Careful selection for several years of Minnesota 13 corn produced a Morris strain of that variety. This strain has met with approval because of its early maturing qualities and its general adaptability to a medium-length growing season. It has been widely distributed and has greatly stimulated diversified farming methods. In co-operation with agronomists of the central station, various single and double crosses have been studied and introduced.

In early years little or no alfalfa was grown in this region, but largely as a result of the successful crops obtained from it at this station,

and the efforts made by members of the station staff to popularize it, it is now the most common hay crop of this part of the state.

For 13 years alfalfa was studied as a rotation crop. Results clearly indicated that under climatic conditions similar to those of the station, corn is the most satisfactory crop to follow alfalfa, and that the place for grain crops is in the later years of the rotation.

Rotations suitable to the territory have been worked out and varietal trials have been conducted in co-operation with the Division of Agronomy and Plant Genetics at the central station. Tests have been made in the breeding nursery of several thousand individual strains and selections of grains and flax, and seed of the more promising varieties has been increased and distributed.

Horticulture

Plantings begun in 1917 and continued yearly have proved that prairie homes of the Morris territory may produce their own fruit by using adapted varieties which have been tried out at the station. In 1930 a demonstration orchard of 800 trees was started.

The comparative value of trees and shrubs for farm planting have been determined at the station. In 1914 more than 2,000 trees and cuttings were set out in the nursery and on the campus and each year since many specimens have been added. This work has led to the establishment of many windbreaks and ornamental plantings on farmsteads, around city homes, and in public parks.

A perennial garden has been established as a demonstration planting and furnishes ideas for many visitors for plantings of their own.

Animal Husbandry

Experimental work in fattening lambs has been in progress for nine years and has attracted national attention. Farmers have been benefited by the information obtained as to the most satisfactory feeds and methods for fattening lambs. Comparisons in feeding value have been made of all the common farm grains, protein supplements, and roughages.

Swine crossbreeding has been under study since 1929 in co-operation with the central station at St. Paul and the Crookston station. In these trials crossbred pigs have shown a definite advantage over purebreds in rate and economy of gains.

Continual improvement of livestock in the west central district can be traced to the influence of the herds and flocks maintained at the station.

Poultry

The poultry department has developed a good egg strain of Single Comb White Leghorns. From the flock, breeding stock is available to

farmers. Experiments have shown that egg production and hatchability of eggs are increased by the use of cod liver oil in the winter ration of pullets. Iodine feeding did not improve total egg production, fertility, hatchability, or affect adult mortality.

THE SOUTHEAST BRANCH

When the land for this station was purchased it was so cut up by ponds, sloughs, and mud holes that only the irregular patches of higher ground could be farmed. The intention was to make this a drainage and farm management demonstration. Some tiling was done and, combined with dry weather and the general lowering of ground water levels, this has made it possible to cultivate almost every foot of land except in very wet seasons. Since 1921 extensive experiments have been conducted in plant and animal husbandry. The station produces registered seed of crops especially recommended for southern Minnesota, thus assuring growers a safe source of pure seed when their own stocks become mixed.

Swine Inbreeding

An unusual achievement of the station is the continuous brother-sister mating of Poland China swine for eight successive generations. So far as is known, this is the first time the close inbreeding of larger farm animals has been carried for so many generations.

The purpose of the inbreeding experiment is to test this mode of attack on swine problems such as feeding efficiency, disease resistance, and the segregation of animals pure for certain desirable characters. Inbreeding and crossbreeding is now accepted as the most promising method of corn improvement, and indications are that the principles are equally applicable to swine.

Cattle Breeding

A herd of 25 grade milking Shorthorn cows was assembled about 1916 in an attempt to determine the possibility of producing beef and butterfat from the same herd. Purebred bulls of beef conformation and heavy milking ancestry were used consistently. After 10 years the selected progeny of these original cows made a fairly uniform herd, averaging 300 pounds of butterfat per cow and producing steer calves capable of earning top prices at the South St. Paul market.

The greatest difficulty encountered was to find sires possessing the desired characters. There was too much chance that offspring would be lacking in one or both of the inherited qualities necessary for dual-purpose performance. In 1930 a new project was set up with the object

of trying close breeding as a means of producing bulls more pure in their inheritance of high production. This must be in progress several years before the desired characters can be obtained and segregated.

Corn Improvement

The first agronomic research undertaken at the station was corn breeding. This project has grown in size and importance each year. Double crosses of both white and yellow corn have been made from long-time inbreds, and additional strains are now ready for testing. High-yielding strains with great resistance to lodging have been obtained. All of this work is under the direction of the plant geneticists of the Central Experiment Station.

The best varieties obtainable from farmers have been compared with the best station productions. As a result, Golden King was introduced in southwestern Minnesota, where it seems to meet a real need. The reaction of given strains of corn to local conditions is also being studied. Apparently crossbred corn is not affected by changed environment nearly so much as is an open pollinated variety.

Approximately 2,000 plots are used annually for the purpose of comparing new varieties of small grains with standard varieties. This work enables the station to make intelligent recommendations to farmers. The fact that an estimated 80 per cent of the small grain grown in southern Minnesota is of varieties recommended by the University is an indication of the value of this work.

THE NORTHEAST BRANCH

This branch was established in 1913, pursuant to the legislative enactment of 1911. It serves the "red drift" clay loam area of upper Minnesota. This type roughly covers the east portion of the conifer country as distinct from the "grey drift" sandy loam of the west portion.

Land Clearing

Procedure for the economical reclamation of stump and stone land, in the cut-over country, has been devised at this station and adopted and used by the United States Department of Agriculture.

Likewise, from extended tests made throughout the district, procedure for the profitable use of pine stumps for fuel has been outlined and published. Up to 16 cords per acre have been realized. With a modest value on the fuel, the land clearing costs nothing—a by-product, as it were, of fuel production.

Horticulture

The station orchard is one of the oldest and most extensive in upper Minnesota. Fertilization of trees with nitrates has helped to bring them into bearing; formerly they seldom got beyond the blossom stage.

Experiments have established the regional superiority of the Underwood plum, the Hibernial apple for volume, the Bruce and Minnesota No. 423 for earliness, the Viking raspberry, London market currant, and Como gooseberry.

Potato bloom is more profuse and extended in cool, moist locations. At times bloom has been present in the station trial plots as late as September 1. Hence for years the station has specialized in potato breeding work, co-operating with the scientists of the Central Experiment Station in St. Paul and of the United States Department. The seedling "19-9-C" has a three-year production record surpassing that of all the old standard varieties.

By straight selection, the Arrowhead sunflower was developed, which is now being distributed as a silage plant through commercial seed trade channels for the first time. The Arrowhead rutabaga, another station-developed plant, is said by pathologists to be practically disease-free.

Co-operative Field Tests

For 10 years co-operative field tests have been maintained with varieties of small grains and with fertilizers on potatoes and roots. Last year there were 60 projects at 20 centers, forage crops being included for the first time.

There are three objectives in this work: the station gets closer to its constituency, the farmer gets the benefit of this visual education, and local soil and crop needs are studied at first hand.

Emphasis has been placed on the worth of early planting for the short northern season. Repeated trials have shown material gains in yields of various crops from this practice.

Outlying co-operative field tests have firmly established Anthony oats on the clay loam soils of the timbered counties.