

The University of Minnesota

**TWENTY-EIGHTH ANNUAL
REPORT OF THE
AGRICULTURAL EXPERIMENT STATION**

JULY 1, 1919
TO JUNE 30, 1920



UNIVERSITY FARM, ST. PAUL

LETTERS OF TRANSMITTAL

MINNEAPOLIS, MINNESOTA,
NOVEMBER 12, 1920

To His Excellency, John A. A. Burnquist,
Governor of Minnesota.

SIR: I have the honor to transmit to you herewith the annual report of the Agricultural Experiment Station of the University of Minnesota for the fiscal year ending June 30, 1920.

Respectfully,
FRED B. SNYDER,
President of the Board of Regents

UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MINNESOTA,
NOVEMBER 12, 1920

The Hon. Fred B. Snyder,
President of the Board of Regents, University of Minnesota.

SIR: I have the honor to transmit herewith the report of the Director of the Agricultural Experiment Station of the University of Minnesota for the fiscal year ending June 30, 1920.

Respectfully,
LOTUS D. COFFMAN,
President of the University of Minnesota

UNIVERSITY FARM, ST. PAUL, MINNESOTA,
NOVEMBER 12, 1920

Lotus D. Coffman,
President of the University of Minnesota.

SIR: I have the honor to hand you herewith the annual report of the Agricultural Experiment Station of the University of Minnesota for the fiscal year ending June 30, 1920.

Respectfully,
R. W. THATCHER, Director

THE BOARD OF REGENTS

The Hon. FRED B. SNYDER, Minneapolis	- - - - -	1922
The President of the Board		
LOTUS D. COFFMAN, Minneapolis	- - - - -	<i>Ex Officio</i>
The President of the University		
The Hon. J. A. A. BURNQUIST, St. Paul	- - - - -	<i>Ex Officio</i>
The Governor of the State		
The Hon. J. M. McCONNELL, St. Paul	- - - - -	<i>Ex Officio</i>
The Superintendent of Education		
The Hon. JOHN G. WILLIAMS, Duluth	- - - - -	1921
The Hon. A. E. RICE, Willmar	- - - - -	1921
The Hon. CHARLES L. SOMMERS, St. Paul	- - - - -	1921
The Hon. PIERCE BUTLER, St. Paul	- - - - -	1922
The Hon. C. W. GLOTFELTER, Waterville	- - - - -	1922
The Hon. W. J. MAYO, Rochester	- - - - -	1925
The Hon. MILTON M. WILLIAMS, Little Falls	- - - - -	1925
The Hon. GEORGE H. PARTRIDGE, Minneapolis	- - - - -	1926

THE AGRICULTURAL COMMITTEE

The Hon. A. E. RICE, Chairman	The Hon. MILTON M. WILLIAMS
The Hon. PIERCE BUTLER	The Hon. C. W. GLOTFELTER
The Hon. J. M. McCONNELL	The Hon. JOHN G. WILLIAMS
The Hon. C. L. SOMMERS	President LOTUS D. COFFMAN

THE STATION STAFF

ADMINISTRATIVE OFFICERS

- R. W. THATCHER, M.A., D.Agr., Director
- ANDREW BOSS, Vice Director
- A. D. WILSON, B.S. in Agr., Director of Agricultural Extension and Farmers' Institutes
- C. G. SELVIG, M.A., Superintendent, Northwest Substation, Crookston
- P. E. MILLER, B.S.Agr., Superintendent, West Central Substation, Morris
- O. I. BERGH, B.S.Agr., Superintendent, North Central Substation, Grand Rapids
- M. J. THOMPSON, M.S., Superintendent, Northeast Substation, Duluth
- R. E. HODGSON, B.S. in Agr., Superintendent, Southeast Substation, Waseca
- CHARLES HARALSON, Superintendent, Fruit-Breeding Farm, Zumbra Heights (P. O. Excelsior)
- W. H. KENETY, M.S., Superintendent, Forest Experiment Station, Cloquet
- W. P. KIRKWOOD, B.A., Editor
- ALICE McFEELY, Assistant Editor of Bulletins
- HARRIET W. SEWALL, B.A., Librarian
- T. J. HORTON, Photographer
- R. M. WEST, B.S., Secretary

DIVISION OF AGRICULTURAL BIOCHEMISTRY

ROSS AIKEN GORTNER, Ph.D., Agricultural Biochemist
Section of Biochemical Research
ROSS AIKEN GORTNER, Ph.D., Agricultural Biochemist
GEORGE E. HOLM, Ph.D., Agricultural Biochemist
PAUL F. SHARP, B.S., Assistant
WALTER F. HOFFMAN, B.A., Assistant

Section of Cereal Technology
C. H. BAILEY, M.S., Associate Agricultural Biochemist
F. A. COLLATZ, B.S., Assistant

Section of Plant Chemistry
J. J. WILLAMAN, Ph.D., Plant Chemist
C. A. MORROW, Ph.D., Assistant Agricultural Biochemist

Section of Nutrition
R. A. DUTCHER, M.S., Assistant Agricultural Biochemist
CORNELIA KENNEDY, Ph.D., Assistant Agricultural Biochemist

Section of Analytical Service
C. H. BAILEY, M.S., Associate Agricultural Biochemist
*S. D. WILKINS, Special Analyst

Section of Dairy Chemistry
LEROY S. PALMER, Ph.D., Dairy Chemist

DIVISION OF AGRICULTURAL ECONOMICS

JOHN D. BLACK, Ph.D., Agricultural Economist
FRANK ROBOTKA, A.B., Assistant in Marketing Investigations
*C. R. CHAMBERS, M.A., Assistant in Statistics

DIVISION OF AGRONOMY AND FARM MANAGEMENT

ANDREW BOSS, Agriculturist

Section of Plant Breeding
H. K. HAYES, M.S., Plant Breeder
R. J. GARBER, M.S., Assistant Plant Breeder
FRED GRIFFEE, M.S., Assistant

Section of Farm Crops
A. C. ARNY, M.S., Associate Agronomist
F. W. MCGINNIS, M.S., Assistant Agronomist
F. H. STEINMETZ, B.S., Assistant Agronomist
....., Assistant

Section of Coöperative Seed Production and Distribution
T. E. ODLAND, M.S., Assistant Agronomist
A. D. HAEDECKE, Assistant

* Half-time appointee.

Section of Cost of Production Studies

G. A. POND, B.S., Assistant Agriculturist
C. G. WORSHAM, B.S., Assistant Agriculturist
MATILDA MARSHALL, Office Statistician
C. G. HELGESON, Route Statistician at Owatonna
C. O. RUUD, Route Statistician at Windom

Section of Farm Organization
ANDREW BOSS, Agriculturist
L. B. BASSETT, Associate Agriculturist

DIVISION OF ANIMAL HUSBANDRY

*CARL W. GAY, B.S.A., D.V.M., Animal Husbandman

Section of Horse Husbandry
*CARL W. GAY, B.S.A., D.V.M., Animal Husbandman
†N. K. CARNES, B.S., Assistant in Horse Husbandry

Section of Beef Cattle Husbandry
W. H. PETERS, B.S. in Agr., Assistant Animal Husbandman
†N. K. CARNES, B.S., Assistant in Beef Cattle Husbandry

Section of Swine Husbandry
*H. W. VAUGHAN, M.Sc. in Agr., Assistant Animal Husbandman

Section of Sheep Husbandry
P. A. ANDERSON, B.S., Assistant Animal Husbandman

Section of Meats
P. A. ANDERSON, B.S., Assistant Animal Husbandman
A. L. ANDERSON, B.S., Assistant in Meats

DIVISION OF BEE CULTURE

FRANCIS JAGER, Apiculturist
G. C. MATTHEWS, Assistant Apiculturist

DIVISION OF DAIRY HUSBANDRY

C. H. ECKLES, M.S., Dairy Husbandman
J. R. KEITHLEY, M.S.A., Dairy Husbandman, Dairy Manufacture
A. B. RAYBURN, B.S., Assistant Dairy Husbandman, Dairy Stock and Production
M. H. FOHRMAN, M.A., Assistant Dairy Husbandman, Testing Laboratory
HAROLD MACY, B.S., Assistant Bacteriologist, Dairy Bacteriology

DIVISION OF ENTOMOLOGY AND ECONOMIC ZOOLOGY

W. A. RILEY, Ph.D., Entomologist and Parasitologist
A. G. RUGGLES, M.A., Entomologist (State Entomologist)
F. L. WASHBURN, M.A., Economic Zoologist
WILLIAM MOORE, A.B., Associate Entomologist, Insecticidal Investigations
R. N. CHAPMAN, Ph.D., Assistant Entomologist, Stored Products Insect Investigations
H. H. KNIGHT, Ph.D., Assistant Entomologist, in charge of Collections
L. V. FRANCE, M.S. in Agr., Research Assistant in Entomology
S. A. GRAHAM, M.F., Research Assistant, Forest Insect Investigations
W. C. COOK, B.S., Assistant in Entomology
*V. R. HABER, M.A., Assistant in Entomology
*ANNA WENTZ, M.S., Assistant in Entomology

* Resigned at end of year.
† Resigned during the year.

DIVISION OF FARM ENGINEERING

WILLIAM BOSS, Agricultural Engineer

DIVISION OF FORESTRY

E. G. CHEYNEY, B.A., Forester
J. P. WENTLING, M.A., Associate Forester
†J. H. ALLISON, M.F., Associate Forester
W. H. KENETY, M.S., Superintendent, Cloquet Station
G. H. WIGGIN, B.S. in For., Assistant Forester at Cloquet
T. S. HANSEN, B.S. in For., Assistant Forester at Cloquet

DIVISION OF HORTICULTURE

W. H. ALDERMAN, B.S., Horticulturist

Section of Pomology

W. G. BRIERLEY, M.S., Associate Horticulturist
†A. W. HILDRETH, B.S., Assistant in Horticulture

Section of Fruit Breeding

M. J. DORSEY, Ph.D., Associate Horticulturist
J. H. BEAUMONT, M.S., Assistant Horticulturist

Section of Vegetable Gardening

W. T. TAPLEY, M.S., Assistant Horticulturist
F. H. KRANZ, B.S., Assistant Horticulturist
†JOHN W. BUSHNELL, B.S., Assistant in Horticulture

Section of Floriculture and Landscape Gardening

LEROY CADY, B.S., Associate Horticulturist
L. SANDO, Florist

DIVISION OF PLANT PATHOLOGY AND BOTANY

E. M. FREEMAN, Ph.D., Plant Pathologist and Botanist

Section of Plant Pathology

E. C. STAKMAN, Ph.D., Associate Plant Pathologist
F. JEAN McINNES, B.S., Mycologist
*G. R. BISBY, Ph.D., Assistant Plant Pathologist
†H. D. BARKER, M.S., Assistant in Plant Pathology
†G. F. PUTTICK, B.S., Assistant in Plant Pathology
†LOUISE T. DOSDALL, M.A., Assistant in Plant Pathology

Section of Seed Laboratory

ROBERT C. DAHLBERG, B.S., Seed Analyst
A. H. LARSON, B.S., Assistant Seed Analyst
BEATRICE LARSON, M.S., Assistant Seed Analyst
RUBY URE, Assistant Seed Analyst
†HAROLD BORST, B.S., Assistant Seed Analyst

Section of Plant Physiology

L. I. KNIGHT, Ph.D., Plant Physiologist
†FREEMAN WEISS, B.S., Assistant in Plant Physiology

* Resigned during the year.

† Part-time appointee.

‡ On leave of absence until Jan. 1, 1920.

DIVISION OF POULTRY HUSBANDRY

A. C. SMITH, B.S., Poultry Husbandman

DIVISION OF SOILS

F. J. ALWAY, Ph.D., Soils Chemist
CLAYTON O. ROST, Ph.D., Associate Soils Chemist
PAUL R. McMILLER, M.S., Assistant Soils Chemist
GUY R. MCDOLE, M.S., Assistant Soils Chemist
GEORGE H. NESOM, B.S., Field Assistant
JAMES E. CHAPMAN, M.S., Field Assistant
WILLIAM M. SHAW, M.S. Assistant
GEORGIA G. DURKIN, Assistant

DIVISION OF VETERINARY MEDICINE

C. P. FITCH, D.V.M., Animal Pathologist and Bacteriologist

Section of Animal Pathology and Bacteriology

C. P. FITCH, D.V.M., Animal Pathologist and Bacteriologist
W. A. BILLINGS, D.V.M., Assistant Pathologist
†D. C. BEAVER, D.V.M., Assistant in Pathology

Section of Veterinary Biological Products

H. C. H. KERNKAMP, D.V.M., Assistant Veterinarian

Section of Veterinary Medicine and Pathology

W. L. BOYD, D.V.S., Assistant Veterinarian

Section of Veterinary Physiology

EARL A. HEWITT, D.V.M., Assistant Veterinarian

Section of Veterinary Sanitation

M. H. REYNOLDS, D.V.M., Veterinarian

† Part-time appointee.

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TWENTY-EIGHTH ANNUAL REPORT AGRICULTURAL EXPERIMENT STATION

FINANCIAL STATEMENT

THE MINNESOTA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATIONS, 1919-1920

Dr.		
To receipts from the Treasurer of the United States in accordance with the appropriation for the fiscal year ending June 30, 1920, under the Act of Congress approved March 2, 1887.....	\$15,000.00	
Cr.		
By salaries	\$15,000.00	\$15,000.00
Total Hatch Fund.....	\$15,000.00	\$15,000.00

Dr.		
To receipts from the Treasurer of the United States in accordance with the appropriation for the fiscal year ending June 30, 1920, under the Act of Congress approved March 16, 1906.....	\$15,000.00	
Cr.		
By salaries	\$15,000.00	\$15,000.00
Total Adams Fund.....	\$15,000.00	\$15,000.00

ABSTRACT I—SALARIES

	Hatch fund	Adams fund
Director and other administrative officers.....	\$3,000.00	
Scientific staff	9,250.00	\$14,400.00
Assistants to scientific staff.....	2,750.00	600.00
Total	\$15,000.00	\$15,000.00

SUPPLEMENTARY STATEMENT

To receipts from other sources than the United States for the year ending June 30, 1920
 State appropriations.....\$257,173.10
 Hog cholera serum..... 32,686.19
 Sales of farm products, etc..... 82,842.78
 Miscellaneous 1,256.65

Total.....\$373,958.72

	University Farm	Crookston substation	Morris substation	Grand Rapids substation	Duluth substation	Waseca substation	Zumbra Heights substation	Total
Salaries	\$114,692.10	\$12,996.48	\$13,045.60	\$4,980.00	\$2,500.00	\$1,800.00	\$3,200.00	\$153,214.18
Labor	37,531.88	6,344.92	3,768.68	9,024.38	6,453.24	5,623.48	3,395.82	72,142.40
Publications	2,251.17	388.52	225.15	.....	.....	.....	.....	2,864.84
Postage and stationery.....	5,323.98	984.68	718.03	534.92	186.09	81.20	48.07	7,876.97
Freight and express.....	1,508.03	349.76	254.67	535.39	50.71	79.51	32.31	2,810.38
Heat, light, water, & power	13,141.07	3,357.00	3,182.23	1,137.53	84.03	382.17	622.43	21,906.46
Chemicals & lab. supplies	27,559.83	10.28	20.28	30.05	.....	.....	.....	27,620.44
Seeds, plants, & sund. sup.	3,969.79	817.92	475.20	1,148.54	463.97	454.46	82.60	7,412.48
Fertilizers	103.65	.....	.....	.....	.....	.....	.....	103.65
Feeding stuffs	9,921.66	2,192.48	2,458.32	6,116.41	2,415.00	1,824.75	261.49	25,190.11
Library	686.99	254.84	74.60	10.00	.....	.....	.....	1,026.43
Tools, mach., & appliances	2,004.65	720.44	708.08	452.47	130.79	390.60	28.40	4,435.43
Furniture and fixtures.....	1,857.53	230.28	1,439.48	127.08	41.36	90.00	36.00	3,821.73
Scientific appar. & specim.	1,559.57	.....	.....	.....	.....	.....	.....	1,559.57
Livestock	4,905.26	490.00	174.00	1,823.00	757.50	715.50	.....	8,865.26
Traveling expenses	5,612.18	802.12	394.40	455.83	293.28	60.02	.....	7,617.83
Contingent expenses	6,399.52	1,482.08	1,289.32	1,105.58	1,128.29	1,085.25	368.26	12,858.30
Buildings and land.....	3,209.04	1,340.52	1,378.92	3,955.52	986.24	1,663.57	98.45	12,632.26
Total	\$242,237.90	\$32,762.32	\$29,606.96	\$31,436.70	\$15,490.50	\$14,250.51	\$8,173.83	\$373,958.72

REPORT OF THE DIRECTOR
FINANCIAL STATEMENTS

In accordance with the plan inaugurated last year, the financial statements presented in this report include only the summarized reports which are submitted annually to the Office of Experiment Stations of the United States Department of Agriculture. The detailed reports of all expenditures of the entire Department of Agriculture of the University of Minnesota, which were formerly presented in the annual reports of the Experiment Station, are printed in full in the Biennial Report of the Board of Regents.

Attention should be called to the fact that the former practice of appropriation by the state legislature of special funds for agricultural investigations is no longer followed. The expenses of maintenance of the work of the Agricultural Experiment Station are carried as a part of the budget allotments to the various sections and divisions of the University Department of Agriculture. At the close of each fiscal year, a review of the distribution of expenditures for that year for collegiate and sub-collegiate instruction, for experiment station work, and for agricultural extension work and short courses, is prepared and presented to the president of the University and printed as a part of the president's annual report. Hence, the reports of expenditures of the Department of Agriculture which were formerly included in the financial statements, as a part of the annual report of the director of the experiment station, are now to be found in the other publications of the University mentioned above, copies of which are available for free distribution upon application to the office of the president of the University, Minneapolis, Minnesota.

CHANGES IN ORGANIZATION

The plan to organize the work in agricultural engineering into two divisions, to be known respectively as Farm Engineering and Drainage, these to constitute the Agricultural Engineering Group, was temporarily postponed because of changes in personnel of the staff. The work in drainage will be carried, for some time at least, as a section of the Division of Farm Engineering, and the organization of the Division of Drainage will be postponed until more definite plans for the future are possible.

With the appointment of W. H. Alderman as Chief of the Division of Horticulture at the beginning of the academic year, a reorganization of the work of that division into the four sections of Pomology, Fruit Breeding, Vegetable Gardening, and Horticulture and Landscape

Gardening, was made. This organization follows more closely than did the former arrangement, the natural grouping of the instructional, research, and extension work in horticulture. It has already shown beneficial results in improving the progress of investigations and the administration of the work in this field.

The addition of an associate dairy chemist and an assistant dairy bacteriologist, to the staffs of the divisions of Agricultural Biochemistry and of Dairy Husbandry, respectively, has made possible the organization of a section of dairy chemistry in the first of these divisions, and the inauguration of important series of investigations of the chemistry and bacteriology of milk and its products.

CHANGES IN STAFF

There were fewer changes in the personnel of the staff during the year than for many preceding years. Some important additions were made. There were few resignations from positions of responsibility for research work. Most of the changes in personnel were among the assistants who carry on the detail work of the several projects under supervision of project leaders; so that the continuity of the investigational work was less disturbed this year than in former years. The changes during the year were as follows:

Agricultural Biochemistry.—Cornelia Kennedy returned to service after a year spent in graduate study at Johns Hopkins University. Leroy S. Palmer was added to the staff as dairy chemist. Lucy G. Dorsey resigned as research assistant and S. O. Werner as special analyst, and Walter F. Hoffman was appointed as research assistant.

Agricultural Economics.—W. W. Cumberland, who had been on leave of absence since his appointment as chief of this division, resigned during the year, and John D. Black, who had been acting as agricultural economist, was promoted to fill the vacancy.

Agronomy and Farm Management.—C. P. Bull resigned as associate agronomist October 1, and F. E. Odland was appointed assistant agronomist in charge of the work of cooperative seed production and distribution. F. W. Peck was on leave of absence until January 1 and on that date tendered his resignation in order to continue in charge of the cost accounting work of the Office of Farm Management of the United States Department of Agriculture. G. A. Pond was appointed assistant agriculturist in charge of studies of cost of production, and C. G. Worsham was added to the staff, also as assistant agriculturist. Matilda Marshall was made office statistician for these studies, and C. G. Helgeson and C. O. Ruud were employed as route statisticians. Fred Griffie was added to the section of plant breeding as an assistant.

Animal Husbandry.—W. K. Carnes resigned as assistant in beef cattle husbandry on March 1. C. W. Gay and H. W. Vaughan tendered

their resignations as chief of the division and as head of the section of swine husbandry, respectively, to take effect at the end of the year.

Dairy Husbandry.—R. M. Washburn resigned as dairy husbandman in charge of dairy manufactures January 1, and was succeeded by J. R. Keithley, formerly of the North Dakota station and the United States Department of Agriculture. J. C. Cort resigned as associate dairy husbandman in charge of dairy stock and production October 1, and Allan R. Rayburn was appointed assistant dairy husbandman. E. O. Hanson, who had been for many years in charge of advanced registry testing, resigned May 1 and M. H. Fohrman was appointed to fill the vacancy. Harold Macy was appointed as dairy bacteriologist September 1.

Entomology and Economic Zoology.—S. A. Graham was on leave of absence for four months for special investigations of insect damage to forests in Canada. V. R. Haber was also on leave for three months and at the close of the year tendered his resignation as research assistant.

Forestry.—J. H. Allison was on leave of absence from November 1 to the end of the year for special investigations in forest management in Arizona, for the United States Forest Service.

Horticulture.—W. H. Alderman was appointed horticulturist and chief of the Division of Horticulture, beginning September 1. W. D. Valleau, who had been on leave of absence for war service, resigned his position as assistant horticulturist in order to become plant pathologist of the Kentucky station, and was succeeded by J. H. Beaumont. W. T. Tapley was appointed assistant in horticulture and at the close of the year was promoted to assistant horticulturist in charge of vegetable gardening investigations. E. L. Proebsting resigned, and John W. Bushnell and A. W. Hildreth were appointed assistants in horticulture.

Plant Pathology and Botany.—Guy R. Bisby resigned May 1 as assistant plant pathologist, and A. G. Newhall October 1 as assistant in plant pathology.

Soils.—J. E. Chapman was made field assistant in soils and Georgia Durkin was added to the staff as assistant in soils, at the beginning of the year.

Veterinary Medicine.—Earl A. Hewitt was appointed assistant veterinarian to inaugurate investigations in animal physiology; and D. C. Beaver, research assistant in animal pathology.

PUBLICATIONS

The plan of distributing station publications only in response to requests for individual numbers was continued. Even with this precaution to insure that the bulletins go only to those who are sufficiently interested in them to send personal requests, the demand for our publica-

tions exceeds our ability to meet it with the funds which are available for this purpose. In the near future, we shall have to still further curtail our publications unless additional funds for making public the results of our investigations can be supplied.

During the year, 45,265 copies of Experiment Station bulletins and 141,449 copies of Extension bulletins and circulars were mailed out in response to requests. The Farm Press News is mailed regularly to 3,100 addresses, and the News Letter to approximately 1,000. There are about 10,000 names on the mailing list to which announcements of bulletins are sent as they are issued. The exact number of addresses on any such list varies from week to week as corrections and additions are received.

The following publications were issued since the last annual report:

EXPERIMENT STATION SERIES

Bulletin 183. First Generation Crosses Between Standard Minnesota Corn Varieties, by H. K. Hayes and P. J. Olson, Division of Agronomy and Farm Management. 24 pages. 5,000.

Bulletin 184. Farmers' Cooperation in Minnesota, by J. D. Black and Frank Robotka, Division of Agricultural Economics. 64 pages. 8,000.

Bulletin 185. Cider- and Vinegar-Making Qualities of Minnesota Apples, by W. G. Brierley, Division of Horticulture. 34 pages. 5,000.

Bulletin 186. Cockroaches in Minnesota, with Special Reference to the German Cockroach, by V. R. Haber, Division of Entomology and Economic Zoology. 16 pages. 10,000.

Bulletin 187. Sorghum and Sorghum Sirup Manufacture, by J. J. Willaman, Division of Agricultural Biochemistry. 56 pages. 8,000.

Bulletin 188. Agricultural Value and Reclamation of Minnesota Peat Soils, by F. J. Alway, Division of Soils. 136 pages. 8,000.

Bulletin 189. Forced vs. Delayed Methods of Clearing Stump Land, by M. J. Thompson, Northeast Demonstration Farm and Experiment Station. 32 pages. 5,000.

Bulletin 190. Potato Diseases in Minnesota, by G. R. Bisby, Division of Plant Pathology and Botany, and A. G. Tolaas, in charge of potato seed certification. 44 pages. 10,000.

Bulletin 191. A Helminthosporium Disease of Wheat and Rye, by Louise J. Stakman, formerly of the Division of Plant Pathology and Botany. 24 pages. 5,000.

Bulletin 192. The Use of Bordeaux Mixture for Spraying Potatoes, by G. R. Bisby, Division of Plant Pathology and Botany; and A. G. Tolaas, in charge of potato seed certification. 32 pages. 10,000.

Two were reprinted:

Bulletin 130. Feeding Dairy Cows, by T. L. Haecker, Division of Animal Nutrition. Pocket size, 64 pages. 10,000.

Bulletin 163. Investigations in Cost and Methods of Clearing Land, by M. J. Thompson, Northeast Demonstration Farm and Experiment Station. 32 pages. 5,000.

ANNUAL REPORT SERIES

Annual Report, Northwest Substation, Crookston, by C. G. Selvig, Superintendent. 32 pages. 3,000.

Annual Report, West Central Substation, Morris, by P. E. Miller, Superintendent. 48 pages. 1,500.

Two-year Report, Northeast Substation, Duluth, by M. J. Thompson, Superintendent. 28 pages. 1,500.

Five-year Report, North Central Substation, Grand Rapids, by O. I. Bergh, Superintendent. 80 pages. 3,000.

General Report, 1913-1918, Southeast Substation, Waseca, by Andrew Boss. 20 pages. 1,000.

Annual Report, Southeast Substation, Waseca, by R. E. Hodgson, Superintendent. 16 pages. 1,000.

AGRICULTURAL EXTENSION SERIES (MINNESOTA FARMERS' LIBRARY)

Two were reprinted:

No. 39. The Minnesota Seed Law, by E. M. Freeman and W. L. Oswald, Division of Plant Pathology and Botany. 8 pages. 15,000.

No. 63. Milk: a Cheap Food, by Flora Rose. (Reprint of Lesson III, Cornell Reading Course for the Farm Home.) 8 pages. 5,000.

SPECIAL SERIES

No. 44. Cafeteria Standards and How to Attain Them, by Nola Treat and Lenore Richards, Division of Home Economics. 8 pages. 5,000.

No. 45. The Bread-Making Project for 1920, by Mrs. Margaret B. Baker, Division of Agricultural Extension; and Mildred Weigley, Division of Home Economics. 16 pages. 15,000.

No. 46. The Garment-Making Project, by Clara M. Brown and Edna R. Gray, Division of Home Economics. 48 pages. 10,000.

No. 47. The Pig Club Project, by L. H. Fudge, Division of Agricultural Extension; and H. W. Vaughan, Division of Animal Husbandry. 4 pages. 10,000.

No. 48. How to Fight the Dangerous House Fly, by W. A. Riley, Division of Entomology and Economic Zoology. 8 pages. 25,000.

No. 49. Queen Rearing, by G. C. Matthews, Division of Bee Keeping. 8 pages. 5,000.

The following were reprinted:

No. 7. Quack Grass Eradication, by A. C. Arny, Division of Agronomy and Farm Management. 16 pages. 25,000.

No. 37. Belgian Hares as Meat Producers, by F. L. Washburn, Division of Entomology and Economic Zoology. 16 pages. 10,000.

No. 39. Computing Food for the Average American Family, by Lucy Cordiner, Division of Agricultural Extension. 8 pages. 5,000.

No. 29. Garden and Small Fruit Insects and Their Control, by A. G. Ruggles and S. A. Graham, Division of Entomology and Economic Zoology. 32 pages. 10,000.

No. 28. Contagious Abortion of Cattle, by C. P. Fitch and W. L. Boyd, Division of Veterinary Medicine. 20 pages. 3,000.

CIRCULAR SERIES

No. 1. Perennial Sow Thistle, by Andrew Boss, Division of Agronomy and Farm Management; and R. C. Dahlberg, Division of Plant Pathology and Botany. 4 pages. 50,000.

No. 2. Valuable Bulletins and Circulars for the Dairy Farmer and the Manufacturer of Dairy Products, by C. H. Eckles, Division of Dairy Husbandry. 4 pages. 5,000.

No. 3. Hydrocyanic Acid Gas Fumigation in Greenhouses, by William Moore, Division of Entomology and Economic Zoology. 4 pages. 3,000.

No. 4. Seed Wheat for 1920, by A. C. Arny, Division of Agronomy and Farm Management. 4 pages. 63,000.

No. 5. Transplanting Seedling Evergreens, by G. H. Wiggin, Division of Forestry. 2 pages. 5,000.

No. 6. Use of Vinegar Bee, by Lavinia Stinson, Division of Home Economics. 2 pages. 5,000.

MISCELLANEOUS

The University Farm Press News was printed throughout the year, as usual, twice a month; and the News Letter, also carrying information to the newspapers, was issued weekly.

Other publications were:

A reprint of "Back to the Farm," a rural drama by Merline H. Shumway. 48 pages. 5,000.

Smut Treatment for Grains, by the Division of Plant Pathology and Botany. 4 pages. 20,000.

Seed Corn Folder, 50,000 copies; posters, 10,000.

Soybean folder, 8,000.

Disinfecting Seed Potatoes, by Frank Frolik, Division of Plant Pathology and Botany. 4 pages. 25,000.

Land Clearing folders, 20,000; posters, 6,300.

JOURNAL SERIES

Fourteen articles which were approved for publication last year appeared in print during the year. Thirty-six additional manuscripts were approved, twenty of which were published and sixteen were in the hands of editors of various scientific journals at the close of the year, for publication in the near future.

The following is a brief summary of the articles that were published:

No. 151. "Biologic Forms of *Puccinia coronata* on Oats." Preliminary Paper, by G. R. Hoerner. In *Phytopathology*, Vol. IX, No. 8 (August, 1919), pp. 309-314.

Several biologic forms of *Puccinia coronata*, the crown rust of oats, occur. By using six varieties of oats as differential hosts it was possible to distinguish several forms. The use of a larger number may show that there are more forms than those already determined.

No. 152. "Variations in Economy of Gain by Individual Pigs: A Possible Application," by R. C. Ashby and A. W. Malcomson. In *Journal of Agricultural Research*, Vol. XIX, No. 5 (June 1, 1920), pp. 225-234.

Three years' work—individual records on 63 pigs, of which 22 varied more than 10 per cent from the mean requirement of their respective groups, in the amount of grain required per unit of gain. Possibility of more exhaustive investigation laying basis for "register of merit" for meat animals.

No. 160. "Studies of Petiolar Glands in the Plum," by M. J. Dorsey, and Freeman Weiss. In *Botanical Gazette*, Vol. LXIX, No. 5 (May, 1920), pp. 391-406.

A study of the petiolar glands in the plum with the statistical method as a basis of determining disposition as to position and number. With this evidence at hand, certain deductions were made regarding the ancestral type in the plum.

No. 163. "A Study of Sterility in the Plum," by M. J. Dorsey. In *Genetics*, Vol. IV (September, 1919), pp. 417-488.

A study of the causes entering into unfruitfulness in the plum, giving particular attention to the reasons for the three distinct waves of dehiscence found to occur.

No. 164. "An Investigation of the Louse Problem," by Wm. Moore and A. D. Hirschfelder. In *Research Publications of the University of Minnesota*, Vol. VIII, No. 4 (July, 1919), pp. 1-86.

A study of different methods of controlling lice with a few observations on their biology.

No. 167. "Vegetable Investigations Being Conducted by the Experiment Station," by Richard Wellington. In *Minnesota Horticulturist*, Vol. 47, No. 11 (November, 1919), pp. 407-414.

A statement of the work being conducted in the breeding and selection of vegetables at University Farm, with a brief statement concerning the particular kind of work being done with beans, peas, onions, squash, tomatoes, cucumbers, and melons.

No. 168. "Some Notes on the Cause of the Unproductivity of 'Raw' Subsoils in Humid Regions," by P. R. McMiller. In *Soil Science*, Vol. VIII, No. 3 (March, 1919), pp. 233-236.

Vegetation experiments with some western Minnesota subsoils showed that the "rawness," or unproductivity, toward inoculated alfalfa plants may be entirely overcome by an application of soluble forms of potash and phosphoric acid. This indicates that the rawness is due to a lack of available mineral nutrients.

No. 170. "Notes on the Composition of the Sorghum Plant," by J. J. Willaman, R. M. West, D. O. Priestestersbach, and G. E. Holm. In *Journal of Agricultural Research*, Vol. XVIII, No. 1 (October 1, 1919), pp. 1-31.

A study of the periods of maturity at which the maximum sugar is present in the sorghum plant, together with chemical data on those constituents of the juice which may affect the yield or the quality of the sirup.

No. 173. "Vitamine Studies IV. Anti-neuritic Properties of Certain Physiological Stimulants." Preliminary Paper, by R. Adams Dutcher. In *Journal of Biological Chemistry*, Vol. XXXIX, No. 1 (August, 1919), pp. 63-68.

The metabolic stimulant thyroxin, desiccated thyroid gland, pilocarpin hydrochloride and tethelin produced definite relief in avian polyneuritis in a manner similar to the anti-neuritic vitamine.

No. 174. "Additional Records of the Broad Tapeworm, *Dibothriocephalus latus*, in Minnesota," by Wm. A. Riley. In *Journal of the American Medical Association*, Vol. 73 (October 18, 1919), pp. 1186-1187.

Two cases of infestation undoubtedly contracted in Minnesota, proving that the parasite now occurs naturally in this country.

No. 175. "The Genus *Bolteria* Uhler (Hemiptera-Miridae)," by H. H. Knight. In *Bulletin of the Brooklyn Entomological Society*, Vol. XIV, No. 4, 5 (October-December, 1919), pp. 126-128.

Type specimens of *Bolteria amicta*, type of the genus, long regarded as lost and unrecognizable, were found in the Luger collection of insects, material which now forms the basis of the collection of the Division of Entomology and Economic Zoology of the University of Minnesota. *Bolteria picta* Uhler is shown not to be congeneric with the type species, *amicta*, and the new genus, *phylloidea*, is erected for its reception.

No. 176. "The Antiscorbutic Properties of Raw Lean Beef," by R. A. Dutcher, Edith M. Pierson, and Alice Biester. In *Science*, Vol. L, No. 1286 (August 22, 1919), pp. 184-185.

Raw lean beef does not possess antiscorbutic properties so far as these properties can be tested by observations on guinea pigs.

No. 177. "An Experimental Study Upon the Impregnation of Cloth with Pediculicide Substances," by Wm. Moore and R. D. Hirschfelder. In *Journal of Laboratory and Clinical Medicine*, Vol. IV, No. 12 (September, 1919), 4 pages.

A brief note on the use of different chemicals to impregnate underwear with the object of making it louse proof.

No. 178. "Synthetic Production of High Protein Corn in Relation to Breeding," by H. K. Hayes, and R. J. Garber. In *Journal of the American Society of Agronomy*, Vol. 11, No. 8 (November, 1919); pp. 309-318.

A discussion of the effects of inbreeding and cross-breeding is made. Results are presented which show that high protein strains have been isolated through self-fertilization. Crosses between high protein strains gave vigorous F₁ progeny with a protein content over two per cent higher than normal corn varieties.

No. 179. "Controlling Flax Wilt by Seed Selection," by E. C. Stakman, et al. In *Journal of the American Society of Agronomy*, Vol. 11, No. 7 (October, 1919), pp. 291-298.

The results of seven years of selection of flax for wilt resistance are given. They show that wilt-resistant strains are readily obtained by selection. A practical seed-plot method for the control of flax wilt is presented.

No. 180. "A Simple Hydrogen Electrode," by C. H. Bailey. In *Journal of American Chemical Society*, Vol. XLII, No. 1 (January, 1920), pp. 45-48.

A new form of hydrogen electrode is described which has marked advantages over the older types, especially for the rapid determination of the hydrogen ion concentration in agricultural products.

No. 181. "The Function of Vitamins in the Metabolism of *Sclerotinia cinerea*," by J. J. Willaman. In *Journal of the American Chemical Society*, Vol. XLII, No. 3 (March, 1920), pp. 549-585.

The brown rot fungus of peaches and plums can not be grown on a purely synthetic medium, but requires a substance of the nature of a vitamin for adequate growth and reproduction. This vitamin was isolated from a large number of plant and animal materials, and is possibly identical with the water-soluble B of animal nutrition.

No. 182. "A Mouse Oxyurid, *Syphacia obvelata*, as a Parasite of Man," by Wm. A. Riley. In *Journal of Parasitology*, Vol. VI (December, 1919), pp. 89-93.

A round worm of mice is reported as transmissible to man, additional evidence of disease transmission through contamination of food by rodents.

No. 183. "The Diagnosis of Bovine Contagious Abortion," by C. P. Fitch. In *Journal of the American Veterinary Medical Association*, Vol. LVI, New Series Vol. 9, No. 5 (February, 1920), pp. 459-467.

"The Diagnosis of Bovine Contagious Abortion" can be made by: (a) the history of the case, (b) use of the serum tests. The agglutination test is the most valuable of these latter methods. The precipitation test and the abortin test are of little value. The inoculation of guinea pigs is a valuable method for the isolation of *Bact. abortus*.

No. 184. "The Longevity of the Virus of Hog Cholera," by H. C. H. Kernkamp. In *The Cornell Veterinarian*, Vol. 6 (January, 1920), pp. 1-7.

The results indicate that the virulence of hog cholera virus is not destroyed up to approximately three years, if it has been carbolized and kept under low-temperature conditions.

No. 185. "The Nature and Function of the Anti-neuritic Vitamin," by R. A. Dutcher. In *Proceedings National Academy of Science*, Vol. 6 (January, 1920), pp. 10-14.

A general discussion of the probable nature and function of the antineuritic vitamin in animal nutrition, including a summary of work done at the Minnesota Agricultural Experiment Station, bearing upon this question.

No. 186. "The Pectin Relations of *Sclerotinia cinerea*," by J. J. Willaman. In *Botanical Gazette*, Vol. 70 (September, 1920), pp. 221-229.

This fungus secretes three pectic enzymes. By means of them it is enabled to penetrate fruit tissue between the cells, and to maintain the rotted fruit in a firm and hygroscopic condition.

No. 189. "The 'Gold Numbers' of Protalbinic and Lysalbinic Acids," by R. A. Gortner. In *Journal of the American Chemical Society*, Vol. XLII, No. 3 (March, 1920), pp. 595-597.

A study of the colloid chemistry of these compounds. Their "Gold number" is approximately equal to that of gum arabic. Consequently it is suggested that their "protective" action has been much overrated.

No. 190. "On the Origin of the Humin Formed by the Acid Hydrolysis of Proteins IV. Hydrolysis in the Presence of Aldehydes III. Comparative Hydrolysis of Fibrin and Gelatin in the Presence of Various Aldehydes," by Geo. E. Holm and R. A. Gortner. In *Journal American Chemical Society*, Vol. XLII, No. 3 (March, 1920), pp. 632-640.

A continuation of the work reported in Journal Series Paper No. 84. It is a contribution to our knowledge of the protein molecule but can not be abstracted briefly.

No. 191. "Some Characteristics of Open Pollinated Seedlings of the Malinda Apple," by M. J. Dorsey. In *Proceedings Sixteenth Annual Meeting American Society of Horticultural Science* (1919), pp. 36-42.

This is an analysis of nearly 3,000 seedlings of the Malinda apple, setting forth the variations in hardness found during the winter of 1917-18, variations in tree type, time of coming into fruiting, and the proportion of desirable types. In seedlings of this kind, where one parent is known, great variation is found in all the fruit and plant characters.

No. 192. "Comparison of Fall, Winter, and Spring Pruning of Apple Trees in Minnesota," by W. G. Brierley. In *Proceedings Sixteenth Annual Meeting American Society of Horticultural Science* (1919), pp. 102-104.

A report of results from dormant pruning in the winter months.

No. 193. "The Origin of the Humin Formed by the Acid Hydrolysis of Protein V," by R. A. Gortner and G. E. Holm. In *Journal of the American Chemical Society*, Vol. XLII, No. 4 (April, 1920), pp. 821-827.

By the use of fifteen pure amino acids (instead of using proteins as heretofore), it was definitely proved that the black acid insoluble humin of a protein hydrolysate is derived solely from tryptophane, and that, under proper conditions, this fact may be utilized for the quantitative estimation of this important amino acid.

No. 194. "A Phosphate-Hungry Soil," by F. J. Alway. In *Journal of American Peat Society*, Vol. XIII, No. 2 (April, 1920), pp. 108-173.

A report of the first season's experiments on the Golden Valley peat experimental fields, where naturally very unproductive high-lime peat was made productive by the application of phosphate fertilizer; potash, both alone and in combination with phosphate showing no distinct effect upon crop yields.

No. 199. "New and Little-Known Species of *Phytocoris* from the Eastern United States. (*Heteroptera-miridae*)," by H. H. Knight. In *Bulletin of the Brooklyn Entomological Society*, Vol. XV, Nos. 2-3 (April-June, 1920), pp. 49-66, 1 pl.

Describes nineteen new and six named, but little known, species. Figures of the genital structures are worked out and shown for the first time to be reliable criteria for the recognition of the species of *Phytocoris*.

No. 200. "Oviposition by a Cockroach, *Periplaneta americana* Linn," by V. R. Haber. In *Entomological News*, Vol. XXXI (1920), pp. 190-193.

The first detailed observations on the care given the egg case in this species of cockroach.

No. 202. "Vitamine Studies V. The Antiscorbutic Properties of Raw Beef," by R. A. Dutcher, Edith M. Pierson, and Alice Biester. In *Journal of Biological Chemistry*, Vol. XLII, No. 2 (June, 1920), pp. 301-310.

A study of the antiscorbutic properties of raw beef revealed the fact that raw beef possesses practically no antiscorbutic properties. The announcement was also made that data had been obtained which indicated that the nutritive and antiscorbutic properties of summer milk were much superior to those of winter milk.

No. 203. "The Colorimetric Estimation of Tyrosine by the Method of Folin and Dennis," by R. A. Gortner and G. E. Holm. In *Journal of the American Chemical Society*, Vol. XLII, No. 8 (August, 1920), pp. 1678-1692.

A detailed study of the colorimetric method for the estimation of tyrosine showed that tryptophane produced almost as intense a color as did tyrosine. In addition the color developed is not proportional to the concentration of the reactive materials. Because of the peculiar form of the color curves and of the large number of interfering substances, it is concluded that the method is worthless in so far as the quantitative estimation of tyrosine is concerned.

WORK OF THE DIVISIONS

DIVISION OF AGRICULTURAL BIOCHEMISTRY

ROSS AIKEN GORTNER, Chief

Three new projects have been inaugurated during the last year. One of these, an Adams fund project, outlines the investigational work in dairy chemistry. The other two are coöperative in nature, one dealing with the nutritional requirements of certain insects (in coöperation with the Division of Entomology and Economic Zoology) and the other with the question of grain dockage (in coöperation with the Division of Agricultural Economics).

Progress on the various projects may be summarized as follows:

Cereal and flour investigations. Subproject: *Grain storage investigations.*—From data previously accumulated, four manuscripts have been prepared and approved for publication. Material has been accumulated for continuing the work on corn, which work will be in progress the latter part of the current fiscal year.

The "strength" of wheat flour. Subproject: *Colloidal factors which may be involved in flour strength.*—This phase of the work has progressed rapidly. The work of Gortner and Doherty (*Jour. Agr. Res.* v. 13, p. 389-418, 1918) was taken as the starting point and a number of new factors were investigated.

Four flours, a high-grade patent from No. 1 northern spring wheat, a first clear from No. 1 northern spring wheat, and two patents from soft western wheats were used. Determinations of the imbibition

capacity of the gluten in acids indicated that the "strong" flours possessed somewhat better gluten than the best flour used by Gortner and Doherty, while the "weak" flour possessed gluten even less coherent than the samples previously worked with.

Extensive series of determinations were made of (a) imbibition in acids; (b) imbibition in alkalies; (c) the binding capacity of the glutens for acids and bases by (1) the titration method, (2) the electrical conductance method, and (3) the potentiometric method; (d) the gold numbers of the various glutens; and (e) the viscosity of the various glutens dispersed in dilute alkali and acids. Some of the experimental data are not yet compiled, so that final conclusions can not be drawn. However, it is certain that there are marked physico-chemical differences between the strong and weak glutens. These differences are especially noticeable in the imbibition capacity, as noted by Gortner and Doherty, in the viscosity, and in the binding capacity for bases. One interesting observation which this year's work brought to light was that the physico-chemical properties of the glutens which were dried in vacuo, powdered, and remade into a dough, are decidedly altered by the drying process, so that the differences between strong and weak glutens become less marked. This is exactly what might have been anticipated, providing that colloidal factors are involved in gluten strength.

Subproject: *Other factors which may be involved in flour strength.*—A detailed study of the hydrogen-ion concentration and buffer action of various grades of flour has been completed, and the results of this work are now ready for publication. The same is true of the study of the electrical conductivity of water extracts of flours of different grades. The relation of hydrogen-ion concentration to the activity of bakers' yeast has been investigated, but this work is not yet complete and will be resumed later.

Investigation of proposed official methods of analysis.—No samples of the A. O. A. C. were received this year.

The biochemistry of resistance to disease in plants. General.—

(a) In extending the work on the nutrition of *Sclerotinia cinerea*, the organism causing the brown rot of plums, it was found that some substance similar to the water-soluble vitamine of animal nutrition is necessary for the normal development of the fungus. This vitamine occurs in considerable quantity in the juice of plums, peaches, and apples; it occurs very abundantly in the sporophores of other fungi, in pollen, and in yeast, and its presence has been demonstrated in a great variety of other plant and animal tissues. There is some evidence of two vitamines, one for vegetative growth, and one for reproduction. This point is being worked on at present. Another point of importance to be settled if possible is the identity of this vitamine-like substance.

(b) Work is in progress to determine whether the growth of this organism can be used as a quantitative measure of the amount of vitamine in a given substance. In order to do this, the most complete and effective method of separating the vitamine from tissues must be known, and this point in the investigation is being stressed at the present time. The suggestion that yeast can be used to measure the vitamine content of a medium is also being critically examined.

(c) The possible relation of the vitamine content of fruit tissue to disease resistance will be taken up as soon as the problems in (b) have been settled.

(d) The quantitative estimation of pentosans. Considerable experimental work on the quantitative estimation of pentosans has been done during the year. Several new methods were tried out and promising results obtained. One of these is a colorimetric method employing a methyl indole which gives an intense orange color with furfural. Very promising results have been obtained, but additional work is necessary before all the factors involved have been assigned their numerical values.

Subproject: *The enzymes of Sclerotinia cinerea*.—A few corroborative data on the pectic enzymes described in last year's report were obtained, and a paper on this subject was prepared.

Subproject: *The biochemistry of resistance to cereal rust*.—No progress can be reported, as no assistant was available for carrying on the work.

Subproject: *Photosynthesis and translocation in different parts of normal and diseased plants*.—No work was done on this problem.

Analytical service. Subproject: *Analyses and tests of flour for State Board of Control*.—Approximately 40 samples of flour were tested during the year.

Subproject: *Tests of grain for State Board of Grain Appeal*.—Two samples of flax were submitted for oil test.

Subproject: *Chemical composition of silage crops*.—The Duluth substation submitted six samples of silage and the Grand Rapids substation two samples for complete proximate analysis.

Subproject: *Tests of quality of strains of wheat from plant-breeding nursery*.—No samples were submitted.

Subproject: *Tests of quality of varieties of wheat grown by the section of field crops*.—Thirty-four samples of the 1918 crop and sixteen of the 1919 crop wheats were submitted late in the fiscal year for milling tests, and while work will begin on these samples during the closing weeks of the year, it will not be completed until next year. For nitrogen determinations, twenty-nine samples of the 1918 crop and twenty-seven of the 1919 crop were submitted.

Subproject: *Tests of quality of disease resistant hybrid wheats*.—No samples were submitted.

Subproject: *Sugar content and purity of sugar beets*.—Four samples were analyzed.

Subproject: *Analyses of corn for selection of high- and low-protein strains*.—Nitrogen determinations were made in duplicate on 609 samples of corn from individual ears. Part of the labor involved in this work was paid for by the Division of Agronomy and Farm Management.

Subproject: *Ash and silica content of grain straw*.—The determinations were made by a graduate student in Agronomy at no expense to this division.

Subproject: *Analyses of butter, buttermilk, and skimmilk*.—Seven samples of butter were analyzed for calcium, and the moisture in a sample of dried buttermilk was determined.

Subproject: *Tests of oats, corn, and rye for section of field crops*.—Forty-eight samples of the 1918 crop of oats and thirty-eight of the 1919 crop were analyzed for nitrogen and moisture. Six samples of rye, twenty-three of the 1918 crop of corn, and twenty-two of the 1919 crop were analyzed in a similar manner.

Subproject: *Feed analyses for Division of Animal Husbandry*.—One sample was analyzed.

Subproject: *Analyses and tests for Food Administration*.—Completed.

Subproject: *Feed control service for State Dairy and Food Commission*.—Completed.

Subproject. *Miscellaneous analyses*.—Includes feeds, vinegar, beet tops, animal viscera, and sulfuric acid, which were analyzed for outside persons, or for other departments of the University. These involved about fifty determinations.

Fruit storage investigations.—This project has been dormant during the last year because of lack of assistance to push all the projects of the division.

Protein investigations.—Marked progress has been made. We were able gradually to increase our stock of amino acids, in both quantity and variety, and many new problems may be attacked when the supply of amino acids warrants our using them in more than minimal amounts.

We have continued the work on humin formation and have definitely proved that our earlier conclusions were correct, i.e., that the humin formation is due to the presence of tryptophane in the protein molecule. Our proof was made by using a mixture of fifteen pure amino acids in various proportions. In those mixtures which did not contain tryptophane no humin formation was observed, while humin was always formed when tryptophane was present. Incidentally the same experiments showed that "soluble humin" is probably derived from tyrosine.

During the winter we had occasion to apply the method of Folin and Dennis to the colorimetric estimation of tyrosine. We early saw that the method was not accurate when applied to protein material. We accordingly investigated the method very thoroly and ascertained under what conditions it would give accurate results and what substances would interfere. We found that tryptophane, indole, substituted indoles, phenols, uric acid, ferrous iron, cuprous copper, or any other easily oxidizable substances, interfere; and that reliable results can be obtained only when all other easily oxidizable substances are absent. Even then the approximate concentration of the reacting substance must be known, for the form of the color curves indicates that the depth of color developed is not proportional to the concentration of the reacting materials.

Chemical studies of pollen.—It was hoped that active work could be carried out this year, but owing to lack of help progress was impossible.

A study of the nutrition of the honey bee.—It has been impossible to continue work on this project.

Chemical studies on animal nutrition and deficiency diseases.—The year's work in the section of animal nutrition may be grouped under the following heads:

(a) A study of the action of physiological stimulants in avian polyneuritis. It was found that the physiological stimulants, thyroxin, pilocarpine hydrochloride, and tethelin, possess properties similar to anti-neuritic vitamine. This work is being continued with the view of obtaining information concerning the physiological functions of anti-neuritic vitamine.

(b) A study of the antiscorbutic properties of beef. Raw beef was found to possess little or no antiscorbutic properties when fed to guinea pigs.

(c) A study of the relation of the vitamine content of dairy feeds to the vitamine content of cow's milk. (In coöperation with the Division of Dairy Husbandry.) We have observed that spring milk appears to be superior to winter milk in nutritive properties. Experiments are now in progress to study this question in detail. The first half of the problem is nearing completion, and we are now prepared to say that milk from cows fed on a ration low in vitamins is also extremely poor in vitamins and much inferior to milk obtained from the same cows when fed a normal ration.

(d) A study of the effect of heat upon the antiscorbutic properties of milk. (In coöperation with the dairy division.) Experiments are now in progress to ascertain the effect of temperature of heating and length of time of heating upon the antiscorbutic vitamine in milk. Milk is obtained daily from the same cow fed a standard ration which

does not vary from day to day. The fresh milk is heated at various temperatures for varying lengths of time and the antiscorbutic properties are compared with the fresh unheated raw milk. No final conclusions have been reached.

(e) The influence of vitamine preparations upon the growth and development of children. (In coöperation with Dr. Matchen, Pediatrician.) Under-nourished children are being fed concentrated preparations of the water-alcohol soluble vitamine obtained from wheat embryo. The results obtained are very encouraging, but additional data must be obtained before conclusions can be drawn.

(f) The influence of yeast preparations upon the growth and development of growing calves. (In coöperation with the dairy division, C. H. Eckles, leader.) This work (which, if successful, has commercial possibilities) is just beginning.

(g) The relation of color to the amount of fat-soluble vitamine in foods. Experiments are in progress to study the relative quantity of this vitamine in highly colored and pigment-free foodstuffs, but no final conclusions have been reached.

(h) Anatomical and pathological changes in scorbutic guinea pigs. (In coöperation with the departments of Anatomy and Pathology, School of Medicine.) We are producing experimental scurvy in guinea pigs and the anatomical and pathological work is being done under the direction of the departments of Anatomy and Pathology.

(i) Is diet an etiological factor in limberneck in poultry? (In coöperation with the poultry and veterinary divisions.) Diet was not found to be a factor, nor could limberneck be produced experimentally by feeding or injecting the toxin of *B. Botulinus*. All other methods also failed except that when larvae of *Lucilia caesar* (from eggs laid upon limberneck carcasses) were fed, symptoms simulating those of limberneck were obtained.

(j) A study of the influence of vitamine-free diets upon the development of reproductive organs of cockerels. (In coöperation with the poultry division.) White Plymouth Rock cockerels were fed a diet of polished rice. Upon caponizing these birds it was found that the testes had atrophied. If a small amount of green alfalfa is fed with the rice this atrophy does not occur. This study will be continued as time and funds permit.

(k) Is the antiscorbutic vitamine essential for normal growth and development in the albino rat? This work is in progress at the present time, but no decisive information has been obtained except that it is observed that rats which receive orange juice appear to be in better condition than those which have been deprived of orange juice.

(l) A study of the nutritional demands of the guinea pig. Guinea pigs are usually fed oats and water, oats and autoclaved milk, or oats

and hay, in scurvy studies. Work is being conducted to find, if possible, a synthetic diet which is readily eaten by guinea pigs that will be adequate in all respects except for the presence of the antiscorbutic vitamine.

The chemistry of the formation and manufacture of dairy products and factors influencing milk production and the composition of milk. Subproject: *A study of the chemistry and physico-chemistry of churning and the factors which influence churnability.*—No definite results have yet been secured on the main part of the project, namely, the various theories of churning, which it is proposed to study, as there was no opportunity to begin the work until the winter quarter. Progress has thus been confined to certain minor phases of the main problem.

A laboratory technic has been found for producing an homogenization of fat of almost any desired degree of fineness. This will be very useful in the study of the factors involved in the difficult churning of cream from cows in advanced lactation. Such cream is always characterized by having relatively small fat globules.

Opportunity was presented to study the lipase content of milk which appears to be abnormally active in the milk coincident with difficult churning. In this connection the question was studied whether lipase is a normal constituent of cow's milk. An improved technic was worked out for studying lipase in milk in which the lipase of cow's milk was studied for the first time, it is believed, under accurately controlled conditions. This technic was applied to normal herd milk and also to the milk of individual cows in various stages of lactation. The results make it appear doubtful whether a lipase is normally present in appreciable quantity which will actively split the natural fat of the milk. There has been no opportunity to apply this technic to any cases of advanced lactation which show the characteristic conditions of rancidity and difficult churning. Such cases may present entirely different results.

Grain dockage investigations.—(In cooperation with Division of Agricultural Economics.) 1. Survey of dockage in northwestern grain. Members of the division staff have laid out and supervised the detailed work which has involved the mechanical analysis of dockage in about six hundred wheat samples. The Railway and Warehouse Commission has provided the services of a part-time assistant.

2. Study of grain removal methods in vogue by flour mills has involved to date a detailed examination in each of the grain and screenings streams in the cleaning department of three representative flour mills. The work has been handled largely by the assistant mentioned above.

The nutritional requirements of certain insects (Tribolium confusum Duval). (In cooperation with the Division of Entomology and Economic Zoology). During the late summer and early fall of 1919, the project progressed fairly rapidly. Certain mixtures of pure proteins,

carbohydrates, salts, and vitamins were prepared, some of which were known to be inadequate for mammalian nutrition, while others were supposed to be adequate. A large number of the eggs of *Tribolium* were placed in these mixtures and counts were made from day to day of the surviving larvae. Some very interesting data were obtained indicating that perhaps *Tribolium* might be used to detect inadequate diets. However, it was not found possible to continue the work during the winter, owing to lack of assistance and available funds, and the data already obtained must be regarded merely as indicating the desirable course to follow in future experiments.

DIVISION OF AGRICULTURAL ECONOMICS

JOHN D. BLACK, Chief

Farmers' cooperation in Minnesota.—A complete mailing list of the cooperative organizations of the state has been prepared, and the activities of these organizations from 1917-18 to 1919-20 have been analyzed and summarized. Special attention has been given to cooperative livestock shipping associations.

Market business practice.—Under arrangements entered into in September, 1916, the division cooperates with the Bureau of Markets of the United States Department of Agriculture for the investigation of methods of accounting and management of marketing organizations, especially cooperative organizations, and particularly for the promotion of the installation by such organizations of a system of accounting devised by the Bureau of Markets. During the last year, attention has been directed especially to cooperative potato warehouse and shipping associations, wool-shipping associations, creameries, and elevators.

Land settlement.—Individual progress records of more than six hundred settlers in northern Minnesota were studied during the year. The methods of land companies and land agents in selling and colonizing their lands were also examined. Data have been taken from the official records of four counties in northern Minnesota as to the ownership of the land by large landholders. The results of these studies have thrown much light upon the problem of settlement.

Land valuation.—Work has been begun upon the problem of land valuation for purposes of exchange, inventory, and granting of loans.

Farm wages in Minnesota.—A special study has been made of the distribution of wages of farm labor in various parts of Minnesota, variations of wages with season and kind of work to be done, and the correlation of wages with returns to the other factors of production.

Grain dockage.—Data have been gathered as to the practices of local elevators, commission men, mills, etc., in paying for dockage in grain, with a view to suggesting changes in present practices if needed.

DIVISION OF AGRONOMY AND FARM MANAGEMENT

ANDREW BOSS, Chief

SECTION OF PLANT BREEDING

Investigations in cereal breeding.—Coöperative relations have been entered into with the Office of Cereal Investigations of the United States Department of Agriculture, for a continuation of winter-wheat breeding studies. A half-time man has been stationed at University Farm. This will help materially in carrying on the work. Data collected during the year show that we have on hand certain crosses and selections which are among the hardiest in the United States. A few definite crosses have been made in the light of the particular characters which the parental forms contain. Material improvement in winter wheat varieties seems almost certain.

In spring-wheat breeding the mode of attack is largely the same as in previous years. A promising variety discovered by Waldron and Clark, named Kota, which is resistant to many forms of stem rust, will help materially in the breeding work. Crosses of Marquis with Preston and Bluestem are being studied for the purpose of isolating a variety of wheat which is as desirable as Marquis, and which has no greater scab susceptibility than Preston or Bluestem. Heterosis in wheat crosses has been under investigation during the winter months, the plants being grown in the greenhouse.

Studies in rust resistance breeding have been put on a definite coöperative basis with the Office of Cereal Investigations and the section of plant pathology. A study made by one of the graduate students in plant pathology on the inheritance of resistance to two forms of stem rust has given further information regarding the mode of attack in breeding for rust resistance.

In the oat investigations, the chief studies are an attempt to produce a higher yielding variety by crossing two of the highest yielding varieties now grown, and an attempt to produce a high yielding variety resistant to stem rust. As second and third generations are being grown this coming year, results of considerable interest will be available after the end of the crop season. The production of non-lodging varieties is one aim in the breeding studies.

Barley breeding work in coöperation with the Office of Cereal Investigations, has been continued as in previous years. A large series of F_3 and F_4 generations of crosses between smooth-awned varieties and better yielding six-rowed varieties were grown last year. Some of these appeared very promising as compared with Manchuria, Minnesota No. 184. There was a severe epidemic of *Helminthosporium* in the plant-

breeding nursery which showed that Minnesota No. 184 was quite resistant to this organism. Several F_3 generations also showed marked resistance. This has led the section of plant pathology and this section to undertake a study of the inheritance of *Helminthosporium* resistance.

Breeding miscellaneous field crops.—Coöperative timothy breeding work with the section of plant pathology gave further evidence that strains resistant to timothy rust could be isolated. A number of plants have been propagated clonally in the greenhouse for the purpose of determining whether self-fertilization in timothy can be easily carried out.

In the flax studies, which are also in coöperation with the section of plant pathology, two selections have been increased; one of them being placed at the Waseca substation and the other at Crookston.

The red clover project in coöperation with the Grand Rapids substation, has been started. Pedigreed strains from Canadian breeders, as well as numerous commercial sorts, have been placed in a preliminary variety test.

Corn breeding investigations.—The studies in corn breeding have been carried on as previously outlined. The chief point of departure from previous work is the plan to make an extensive application of the theory of inbreeding and cross-breeding for corn improvement. Further land has been made available for these studies.

Inheritance studies with small grains.—One of the principal lines of investigation has been a study of the inheritance of stem rust resistance in oats. A considerable quantity of grain of the F_2 generation was grown this year and a large amount of seed for the F_2 and F_3 generation has been planted. Detailed studies of the inheritance of rust resistance in the progeny from these plantings will be made during the summer of 1920.

Inheritance of seed shape and seed texture in relation to botanical head characters has been continued as in previous years.

SECTION OF FARM CROPS

Investigations with small grains.—No work was done during the year on home-grown oats as compared with seed of the same variety and strain brought from outside. The value of different grades of seed oats was compared on land of medium and low productivity. For the year, there appeared to be an advantage in favor of the heavier seed on land of low productivity. A comparison of primary and secondary oat kinds for seed was continued.

Several grades of wheat were grown on land of medium and of low productivity by both the plot and the individual plant method. Sown at a varied rate on plots to secure approximately the same number

of seeds per acre or at the same number of pounds per acre, there were for the year no significant differences in yields. The work already done on methods of preparation of the seedbed for wheat is being prepared for publication.

Winter rye and wheat were sown at different rates and dates. Seeding early in September appeared to give results superior to seeding early in October.

As a result of the experience of previous years, mixtures of various grains were grown and fair results obtained. Improved technic based on experimental data secured in previous years has brought about a lower probable error in variety trials. Ghirka, Preston, and Stanley A, among spring wheats, yielded better than Marquis or any of the durumms. Among the winter wheats, Minturki, Minhardi, Malakoff, and Buffums No. 17 were the best yielders. Buffums No. 17 is fairly winter hardy, but has rather soft kernels. Swedish, Minnesota No. 2, Wisconsin Pedigree, and Rosen yielded well at University Farm and better than Abruzzes or spring rye. Among the oat varieties, Gold Rain, Irish Victor, Silvermine, Garton, Nursery No. 1-15-33, Garton, Nursery No. 1-15-38, and Iowa No. 103 were the highest yielders for the year. White Tartar, Fulghum, and a hull-less variety were distinctly inferior yielders. Improved Manchuria, Minnesota 184, and Akers Russian were the highest yielders among the barley varieties grown. M. A. C. Robust was the highest yielder among the field beans, with Black Turtle Soup a close second. In the soybean varieties, Habaro, Wisconsin Black, and Elton were less productive of seed than Chestnut, Ito San, Accession No. 182, Pedigree I, Minsoy, and Soysota.

In order to obtain data on sandy soils and on peat, variety testing was extended to very sandy soil at Coon Creek, and to peat at Coon Creek, Fens, and Golden Valley. Fair crops were grown at Coon Creek on both sand and peat and at Fens on peat. At Golden Valley the crops were drowned out.

The study of the relation of size of seed to yield and various plant characters was continued.

Coöperative variety trial of farm crops.—Varieties of grains and forage crops were grown in coöperation with the several substations. Yields are given in the annual reports of the substations.

Forage crop investigations.—The study of the effect of different rates of planting on yield of corn was continued. The work on stage of maturity at which to cut was not carried out on account of labor shortage.

Yields of alfalfa were secured for the year. Some work was done on the inoculation of alfalfa seed by various methods. The results to date do not warrant any statement as to the relative efficiency of the

various methods under test. Yields were secured from the various grasses and legumes sown alone and in mixtures at University Farm, and at Coon Creek and Fens on peat lands. On mineral soils where alfalfa can be sown, mixtures of timothy and alfalfa appear to be worthy of more extensive trial.

Crop rotation investigations.—The usual work was carried out on Fields T and C. The newly laid-out plots growing crops continuously and alternately produced the first crop.

SECTION OF COST ACCOUNTING

Cost accounting investigations on Minnesota farms.—The detailed cost accounting studies conducted by this section, which were discontinued in 1918, were resumed last year in coöperation with the Office of Farm Management, United States Department of Agriculture. A statistical route of twenty-four farms was started at Owatonna, Steele County, January 1, 1920, and another with the same number of farms March 1, 1920, at Windom, Cottonwood County. A statistical agent is stationed at each place who visits each farm at least twice a week. Detailed records are kept of all farm operations and of every phase of the farm business. The results will be summarized and tabulated as a basis for a complete study of the basic factors of cost in farm production.

Survey study of the progress and prosperity of northern Minnesota settlers.—A three-year survey of three areas in northern Minnesota was begun in July, 1919. The localities selected were the areas about Mahnomen, Mahnomen County; Blackduck, Beltrami County; and Grand Rapids, Itasca County. Records were obtained from about sixty-five farms in each area. The average-sized farm at Mahnomen, in a prairie country, was 293 acres, of which 128 acres were in crops. Receipts were largely from crop sales. The Blackduck and Grand Rapids areas were both cut-over land.

The average-sized farm at Blackduck was 162 acres, with an average of 26.5 acres cleared, and the average length of settlement of these farms was 10.5 years. The farms at Grand Rapids averaged 125 acres in size with 36 acres cleared. The average length of settlement was 11.5 years. The average net worth of the settlers at the time of settlement was \$770 at Blackduck and \$653 at Grand Rapids. The average cost of clearing in these two areas was \$55 at Blackduck and \$69 at Grand Rapids. The average acreage cleared annually was 3.3 and 3.5 respectively. The high cost of clearing and the small initial capital made it necessary for the settler to seek employment off the farm in order to get cash enough to support the family. This delays the progress of settlement. Only after the settler has a large enough area cleared to support his family does he make rapid progress. There is a ready

market for forest products, and this is a great help to the settler in making a living on his farm. This survey will be continued in 1920-21.

SECTION OF COÖPERATIVE SEED PRODUCTION AND DISTRIBUTION

A system of inspection and certification of farm seed in coöperation with the Minnesota Crop Improvement Association, has been worked out. More than sixty farmers availed themselves of the opportunity to have their seed stocks inspected and certified. Applications received so far this year indicate that there is a big demand for this work among farmers, and that the number of inspections will be at least three times the total of last year.

At a substation conference held December 28, 1919, a plan was adopted by which the central and substations will coöperate in increasing improved varieties for distribution. Each station is allotted certain acreages of specified varieties which are to be grown for distribution among farmers. The registration system will help to keep the seed from losing its identity after being distributed. This plan, it is hoped, will secure a much wider distribution of varieties which have proved superior in the tests conducted at the various stations.

More than 1,200 bushels of improved seed grown at University Farm were sold to farmers in the state. This included seeds of small grains, corn, soybeans, peas, and various other standard crops. Small lots were used for experimental purposes and for seeding increase fields at University Farm.

Sugar beet seed production.—The coöperative work with the Minnesota Sugar Company in producing sugar beet seed has been discontinued for the present, owing to a change in management of the company. This work was progressing very satisfactorily, and it is hoped that it can be continued later. The production of Elite sugar beet seed at University Farm has been continued. Home-grown seed is furnished to the farm sections for planting. The station will have some of this seed for distribution next year.

DIVISION OF ANIMAL HUSBANDRY

CARL W. GAY, Chief

Plans to begin a series of swine feeding tests were interrupted by an outbreak of pneumonia among the feeding hogs, which ran such a course through all lots as to make feeding trials impossible.

There still being no provision for steer and lamb feeding experiments, no work of this sort was attempted. A complete feeding plant is necessary before any comprehensive investigation in this line can be conducted and it is hoped each year that such equipment may be made available.

Accurate records of maintenance and production costs have been kept on the beef herd, covering cows, bulls, calves, and fattening steers, in separate groups. Inability to obtain competent help has prevented keeping accurate records on horse and sheep production.

DIVISION OF BEE CULTURE

FRANCIS JAGER, Chief

Queen raising.—About one thousand queen bees were raised from pure Italian breeding queens for the improvement of bee stock in the state. Of these, more than seven hundred were sent by mail to all parts of the state, the demand far exceeding the supply, and our own apiaries were requeened with choice tested queens.

Observation hives.—One normal colony of bees was kept on scales outside all the year; another was put on scales in the cellar through the winter. Observations were taken daily and results drawn in diagrams showing the gain of bees for the summer, recording the length and intensity of honey flows, and the losses during the different periods and conditions of winter and spring.

Model apiary.—The apiary at University Farm is modern throughout, with best Italian bees and equipment. Best methods of management for honey production are illustrated for students of the Agricultural College and for a large number of visiting beekeepers, as well as at beekeepers' meetings held at the apiary.

Pollen substitutes.—It was found that wheat flour, rye flour, or gluten flour tho carried into the hive by bees was not fed to brood. Analysis of the food indicates that ordinary flour can never be substituted for pollen; that gluten, being higher in protein content, may yet show positive results.

Bee disease inspection about University Farm.—Bees in the immediate vicinity of the University apiary have been inspected and found free from disease.

Bee and honey survey.—By extension work it is learned that there is a great field in northern counties which is undeveloped bee country; that beekeepers pay too little attention to the blooming of minor plants; that yards of bees are generally inadequately equipped; that the great majority of bees are hybrids; and that winter losses have been enormous this year owing to poor stores, low cellar temperatures, and lack of cellar ventilation.

DIVISION OF DAIRY HUSBANDRY

C. H. ECKLES, Chief

Keeping qualities of butter.—In order to compete in the butter market of the world it is necessary to have a product with good keeping qualities. This project is a study of certain phases of this question.

The tests of the previous year concerning the relation of the temperature of pasteurization to the keeping quality of butter were repeated. The results corroborate those previously obtained to the effect that cream pasteurized at 175 degrees F., a temperature presumably sufficient to destroy the enzymes that may be present, produces butter of better keeping quality than does cream pasteurized at a lower temperature.

An attempt to study the relation of casein content to the keeping quality of butter was largely vitiated by the fact that the experimental lots of butter manufactured according to a system said to give high casein content contained practically the same casein content as the check lots.

Reducing the acidity in cream of inferior quality by partial neutralization before pasteurization resulted in somewhat improved keeping quality in the butter.

The project will require extensive investigations before definite results are obtained.

Raising calves with the minimum amount of milk.—This project was begun during the year. Calves given a good start on milk are doing well on a ration of hay and grain and no milk after the age of 50 days.

Food requirements for growing animals.—This project was also begun during the year. Twelve dairy heifers of varying ages were fed a ration supplying the net energy required according to the Armsby standard for animals of this age and size. A second group of eleven was fed a ration supplying energy 15 per cent below the standard. The results are compared with the normal growth for animals of their size and breed as previously determined. The group receiving 15 per cent below the Armsby standard, as well as that fed the amount prescribed by the standard, made growth equal to or exceeding the normal.

Factors influencing the vitamine content of milk.—This project was begun in January, 1920, in coöperation with the Division of Agricultural Biochemistry. The relation of the ration of the cow to the vitamine content of the milk and the influence of heat upon the vitamins of milk are the specific subjects under investigation. The work has not progressed far enough to justify a report.

Presence of tubercle bacteria in milk and effect of pasteurization on these organisms (In coöperation with the Division of Veterinary Medicine).—Work has begun, but no results are as yet available.

Changes taking place in the bacterial content of morning milk.—The purpose of this project is to study the development of bacteria during the first few hours after it is drawn, with reference to the necessity for cooling.

DIVISION OF ENTOMOLOGY AND ECONOMIC ZOOLOGY

W. A. RILEY, Chief

Truck crop and small fruit insects. Subproject: *Cutworms.*—A comprehensive study of the cutworms and army worms of Minnesota is being conducted. Definite data have been obtained relative to the prevalence, life histories, and methods of control of the principal species. Poison baits are being tried out and it is found that considerable variations in the effectiveness of different formulae are dependent upon species differences. A popular circular has been issued, giving general control measures.

Insects infesting stored food products. Subproject: *Measures for protecting wheat flour substitutes from insects.*—A study was made of the effect of low temperature as a means of protecting cereal products from insects. It was found that a temperature of 43 degrees, F., would prevent all development of the confused flour beetle (*Tribolium confusum* Duval) which is one of the worst pests. These results have already been taken advantage of by one of the largest breakfast food manufacturing concerns in America, for the protection of wheat products which they buy and store in large quantities.

Subproject: *The relative susceptibility of various cereals to insect attack.*—A study of susceptibility as related to the survival and reproduction of insects which have entered the cereals, has resolved itself into a consideration of the ecological succession of the insect pests. Results obtained up to the present seem to justify the following conclusions: (a) The insects which attack sound grain can not survive in milled products. (b) The insects which work in milled products can not survive in sound grain. Grain which has already been attacked by grain insects is in a condition comparable to that of milled products, and is subject to attack by the milled product insects. (c) Moist and moldy products are subject to attack by insects which require fungus for their diet. (d) In advanced stages of decay, the insect fauna is similar to that found in any decaying plant or animal products.

The moisture content of the material may make it impossible for insects to develop rapidly, if at all. Each insect appears to have a very definite moisture requirement. The nutritive value of the material may influence the rate of growth and the percentage of survival of the insects. The work on nutrition will be continued.

Life history and methods of control of the chicken nematode.—Detailed studies have been made of the method of infection of chickens by *Heterakis papillosa*. No intermediate host is required, and there is no evidence that the larval forms undergo migrations comparable to those recently discovered for *Ascaris*. The resistance of eggs to various chemicals and to temperatures is being studied for the purpose of testing the efficiency of various recommended methods of soil sterilization.

Parasitic and disease carrying insects and their allies. Subproject: *The Drosophila flies.*—In connection with the work on *Drosophila* flies, attention has been especially directed to their occurrence as a pest and as possible disease carriers in dissecting rooms. Their ability to breed in materials preserved in formalin solutions and in various other reagents is being studied.

Insecticides. Subproject: *Orchard spraying.*—In the orchard spraying experiment the results of the last year's work show that apple scab was better controlled by the use of Nova Scotia bordeaux—calcium arsenate spray than with any other spray used. Dust arsenate of lead, 15 per cent, and sulphur, 85 per cent, gave excellent results. The dusted trees showed fruit with less scab per individual apple than the liquid spray and on the whole gave a better percentage of No. 1 saleable apples. The scab was not well controlled on the plot sprayed with liquid arsenate of lead and lime-sulphur mixture.

Subproject: *Tree tanglefoot investigations.*—In spite of the opinion sometimes held that tree tanglefoot is injurious to trees, no bad results have yet been evidenced, in either the use or misuse of the tanglefoot.

Specific toxicity of various chemicals to insects and their hosts. Subproject: *Study of arsenicals.*—The year's work is based on the assumption that the leaves of plants when wet exhibit a negative electrical charge and that the arsenicals used at the present time also exhibit a negative electrical charge. It was assumed that if an arsenical could be prepared with a positive electrical charge, greater adherence to the foliage would result. Two methods of preparing such positive materials were considered: (1) The addition of electrically positive material such as ferric hydroxide or aluminum hydroxide to the ordinary negative reaction; (2) The preparation of such arsenicals as ferric arsenate or arsenite, or aluminum arsenate or arsenite, with positive charges, thus accomplishing the result directly. Several of these preparations were made and potato plants were sprayed in June. Leaves were collected immediately after the spray had dried, and at different intervals of time. Records of rainfall were kept and later in the year these leaves were analyzed. The extensive data resulting are being correlated and will be reported upon during the coming year.

Some time was spent in making a study of the spreading of sprays over the leaf surface. The rule that spreading will occur if the surface tension of the leaf is greater than the sum of the surface tension of the spray material plus the surface tension at the interface of the spray and the leaf, appears to apply. On leaves with a thick cuticle, excellent results could be obtained by using one-fourth pound of casein to 100 gallons of water, the casein being dissolved in a small amount of sodium hydroxide. Gelatin or an alkaline solution of flour used at the same rate can also be used for spreading for similar leaves. Since spreading is

unsatisfactory on waxy leaves, such as those of cabbage, various chemicals were tested with the idea of overcoming this difficulty by the use of substances which have a decided affinity for the wax of the leaf. Promising results have been obtained.

Endoparasites of man and domesticated animals.—Studies on the rôle of rodents as carriers of gross parasites of man have been continued as reported last year. The work on fish parasites has also been continued and additional evidence of the endemic occurrence of the fish tapeworm of man in this country has been obtained.

Studies of the parasites of domesticated foxes were carried on in coöperation with the Division of Veterinary Medicine and will be reported upon in the near future.

Insect collection.—Approximately four thousand mounted specimens were added to our already extensive insect collection, and important groups of Hemiptera and Coleoptera have been determined. In addition, authoritative determinations of several other groups have been made by specialists.

Field mice and other rodents. Subproject: *Belgian hares an economical food.*—The three strains of domestic rabbits, known as Belgian hares, Flemish Giants, and New Zealand Reds were under consideration. Comprehensive data were obtained on the following points: Cost of raising; feeding (adult, nursing doe, young); comparative rate of development; diseases (notably coccidiosis); proportion of bone to meat; hides and fur and prices of both; breeding; castration; hutch building; marketing. Special bulletin 37, "Belgian Hares as Meat Producers" has been in such demand as to necessitate reprinting and opportunity was taken to revise it thoroly and incorporate new data.

Nursery and orchard inspection. Subproject: *A. General work in nurseries and inspection of imported stock from Europe.*—During the season 157 nurseries were inspected, for many of which certificates of inspection were issued. In addition, 13 special certificates have been issued to dealers in nursery stock. As a rule nurseries were found to be in excellent condition, in spite of very favorable weather for the development of the usual insect pests and plant diseases. No dangerously injurious insects or diseases, necessitating the refusal of a certificate, were found.

Subproject B. *White pine blister rust.*—By the fall of 1919 enough information was obtained to indicate that white pine blister rust is well established in this state and there is no hope of eradicating it or even materially arresting its spread.

As the disease is here to stay, the problem must be one of local control. To control the disease in white pine areas, as a general statement it may be said that all currants and gooseberries, wild and cultivated,

must be eradicated in the forest or planting to be protected, and for at least 600 feet outside of the protected area.

In order to encourage local control of this nature, the state, by an agreement with the Bureau of Plant Industry, United States Department of Agriculture, will cooperate so far as funds are available, with private individuals, associations, or counties, provided such coöperator will bear one-half the expense.

Subproject C. *Barberry eradication.*—In 1919 eradication work was carried on to a large extent in rural communities, with a result that 41,523 bushes were located and removed on 326 farms in fifty-three of the eighty-six counties. These farms are not located in any particular section of the state, but are widely distributed over western, central, and southern Minnesota. Many of these farms no doubt have been infection centers in their counties for many years. It is known that common barberry has been growing on farms in Minnesota for nearly 50 years. In all 16,601 miles were traveled, the work being accomplished by a farm-to-farm canvass by field men in automobiles. In the towns, 13,918 bushes were destroyed in seventy-nine counties. The work done to-date on field survey indicates that there are still many plantings of common barberry to be found. It is evident that entire eradication is more nearly accomplished in the towns and will be completed with much less difficulty there than in rural communities.

DIVISION OF FORESTRY

E. G. CHEYNEY, Chief

Studies in forest regeneration.—(a) Work with exotics was continued. There are no definite results as yet. (b) Counts and measurements made on 600 half-acre reforestation plots at Cloquet and additional plots of the same character were laid out in the rocky regions of the northeastern part of the state to determine the best species and planting methods to use in that section.

Nursery practice on methods of transplanting and management of white spruce was carried on and the work is nearly completed.

Fertilization of seedbeds.—Forty plots were laid out and planted to determine the best fertilizers to use on seed beds and transplants. The results are checked up by weight and measurement.

Damping-off of coniferous seedlings.—Very intensive experiments with a large number of beds were carried through this year to check the results of the experiments started in 1916. The project is now completed and the results are ready for publication.

Injury from deer and rabbits.—Data collected in Itasca Park through a series of years are ready for compilation.

Forest trees of Minnesota.—The collection of specimens and data for the illustrated description of all species of Minnesota trees has been continued.

Windbreaks.—A thoro study of the existing windbreaks in the southwestern and western prairie regions of the state was completed and the results were prepared for publication.

Demonstration plantings of windbreaks have been started in a few of the counties this spring in coöperation with the Division of Agricultural Extension.

Studies in yield and volume.—This project includes the organization of the property of the St. Paul Water Company under a working plan, and a study of the plantations of this property. The work of organization is progressing satisfactorily. The company has increased its planting area this year and seems very well satisfied with the results. A study of the plantation shows that the growth of white pine and Scotch pine in some of the better locations has been remarkably rapid.

Frustrum form factor tables for jack pine, Norway pine, and white pine were worked up and the results published.

Studies in white pine blister rust control.—The first season's work was of a preliminary character and no final results were obtained, but data were collected and many permanent plots established. Results seem to indicate that the effectiveness of *ribes* eradication would depend very largely on the number of sprouts which come up from the roots after the plant has been removed. Indications are that sprouting is much less likely from plants which were cut off below the surface of the ground than from those which were pulled. This will be checked during the coming summer. If it proves to be true, it may radically change the methods of eradication now in use. The project will be continued this year in coöperation with the Bureau of Plant Industry.

Preservative treatment of fence posts.—No new work in treating has been attempted, but careful records were made of the condition of the treated posts in the experimental fences at Zumbra Heights and University Farm. The comparative values of the different treatments are beginning to show.

Effect of structure, time of cutting, and methods of seasoning of white cedar on the penetration of preservatives.—This project was started this year. Some material has been collected and partly seasoned. The work will be continued next year.

Collection of woods.—Many species of woods from all parts of the country have been collected, prepared, sectioned, and filed for use. The work will be continued.

Blueberry culture.—In coöperation with the Division of Horticulture, a suitable bog has been put in shape for the cultivation of hybrids and selected native plants. Groups of native plants showing exceptional fruiting qualities were located and staked during the summer of 1919. They were transplanted to the bog in the spring of 1920. They will be compared with the hybrids from Washington.

DIVISION OF HORTICULTURE

W. H. ALDERMAN, Chief

SECTION OF POMOLOGY

Blueberry culture.—The good blueberry crop of 1919 made possible the selection of forty-four wild plants or colonies of plants of *Vaccinium pennsylvanicum*, all in the vicinity of Cloquet. All these selections were superior in size or quality of berry or excelled in yield of fruit. A large proportion of the crop of one colony averaged slightly more than half an inch in diameter. A few plants or colonies were selected for their pronounced vigor and heavy bloom, and were dug in the spring of 1920. The young rooted shoots from these were planted in a nursery row where they can be cared for to best advantage. They will later be transplanted to a permanent location for fruiting. Very few selections were made of *Vaccinium canadense*, as it was thought that the fruit of this species was not high enough in quality.

The highbush plants (*V. corymbosum*) and highbush x lowbush plants (*V. corymbosum* x *V. pennsylvanicum*) received in 1919 from the Bureau of Plant Industry, United States Department of Agriculture, made a fair growth on the jack pine sand. This spring the majority of these plants were transplanted to the newly prepared bog, and on the edge of the bog where the sand content of the soil gradually increases over the peat content. A few plants from each lot were planted in the sand above the bog for comparison with those set on the bog. The lowbush plants (*V. pennsylvanicum*) in the culture plots in the nursery bore heavily in 1919. Some of them showed markedly the possibilities of this species under cultivation, or when free from competition with other plants. Some plants set and matured several clusters with more than 20 berries to the cluster; other clusters showed from 30 to 40 berries. In a few instances plants from the cultivated plot bore clusters of from 60 to 70 berries, but these large clusters appeared to ripen slowly. Evidently this is a result of overtaxing the strength of the plant.

The culture plots were 4 by 12 feet and 50 plants were set in each in 1917. These small culture plots included trials of cultivation; cultivation and shade (by means of a lath screen); and mulching with two inches of peat, manure and peat, and manure. Check plots with no care were also included. In 1918 and 1919 all plots were watered as needed, and the weeds were pulled. Manure, either alone or in combination with peat, showed a marked detrimental effect. Peat mulch gave the best stand of plants after three seasons, with shade a close second, and cultivation third. The best plant growth was made in the shade plot, with the cultivation plot second, and the peat mulch plot third. In fruiting, the cultivated plot gave the best crop, the best quality

berries, and the largest clusters. Peat mulch was a close second, and shade a rather poor third. As the production of fruit is of chief importance, it appears that either cultivation or a peat mulch will give satisfactory results. While shading gave very good plant growth, it is doubtful if this method is practicable on a large scale.

In a study of the possibilities of increasing the stand of plants in the wild without recourse to burning, square-rod plots were laid out in a favorable location. One plot was grubbed over to remove other wild plants and another was mowed with a brush scythe. Suitable check plots were selected adjacent to these plots. After two seasons it is evident that treatment of either kind stimulates the other wild plants more than the blueberries, and the blueberry plants are being subdued. From this very limited trial and from the good results with cultivation or peat mulch, it is evident that much better results can be obtained on a cultivated area which is kept free of other plants.

Studies have been made of various methods of propagation during the course of the work. Cuttings of all kinds were made in 1916 and 1917. These included young shoots, old wood, young wood on old wood, heel cuttings, root cuttings, and underground stem cuttings. Young shoots with a portion of root attached and young plants with a fairly well developed top and root were also given a trial. The cuttings without roots uniformly did very poorly or failed entirely. Root cuttings appeared to suffer from lack of top. The young plants seemed to be badly checked by the moving, as new growth dries back. Young shoots with a portion of root attached were far superior to all others. They do not dry back seriously and are easy to handle. This method of propagation was followed in planting the culture plots. Of 250 plants set in the five plots for the cultivation, shade, or peat mulch experiment, 218, or 87.2 per cent, developed. From these results it seems safe to rely on this method for the propagation of the lowbush blueberry.

Studies of the natural propagation of wild plants show that the lowbush blueberry (*V. pennsylvanicum*) spreads readily by branching underground shoots. These shoots push out from 6 to 12 inches or more and turn up at the tip. The tip pushes above the surface and develops foliage and branches. The stem gradually develops roots, but the main source of food for the first season is the root system of the parent plant. One vigorous plant may develop into a colony by this sort of propagation. Such colonies frequently cover the ground in the neighborhood of an old stump or log and sometimes cover more than a square rod.

Variety test of fruits.—The usual observations have been made of the behavior of the various fruits under trial. Several apple varieties received from the Central Experimental Farms, Canada, show some

promise for Minnesota conditions, but have not yet fruited. A few trees of Red Duchess, a red sport of the common Oldenburg (Duchess) found in an orchard at Lake Minnetonka, are being developed in the nursery. This sport is of considerable promise on account of the attractive appearance of the fruit.

As the soil at University Farm is not representative of the general type of soils in the state, and as a considerable number of varieties of strawberries and raspberries are being grown at the Fruit Breeding Farm, where conditions are more favorable, a large part of the variety studies with these fruits will be carried on there in the future.

Coöperative orchard management.—The orchard at Rockford bore a fair crop on the 1913 block and some fruit on the 1915 block. The topworking in the 1915 block is practically completed. A new block of 250 trees was set in the spring of 1920. The topworking in the orchard at Newport is completed except on replanted trees. At Willmar some trees have been transplanted to make room for a new building, and were used to fill in gaps where others had failed. In the Duluth orchard there has been a rather high rate of mortality due to several causes. The site is low, the trees set at first were year-old whips, not in the best of condition, and the planting was done on newly cleared land which was too raw for good results with apple trees. The average percentage of mortality for the last two seasons has been: Hiberna 10.05, Patten 10.9, Okabena 10.9, Wealthy 14.4, Anisim 14.6, and Duchess 15.1. Much of this was due to the causes noted plus crown gall infection. The dead trees have been replaced by hardy apples and crabs.

Pruning the apple.—The comparison of the effects of fall and spring pruning has been continued in the coöperative orchards at Willmar, Rockford, and Newport, as well as at University Farm. These orchards have offered an opportunity to note the effects of fall and spring pruning on several apple varieties commonly grown in Minnesota. About fifteen hundred trees are now included in these pruning studies, half of them fall pruned and half spring pruned.

Cost of producing fruits.—Cost records for 1919 have been obtained in the orchards visited in previous seasons. Additional cost records have been obtained for apples and raspberries. Many orchards and berry fields have been visited, which for one reason or another are not suitable for cost data.

Nut culture in Minnesota.—Additional data have been obtained relative to the location and vigor of private plantings of nut trees within the state. Scattered plantings of black walnut in good vigor and bearing have been found south and west of a line from St. Paul through St. Cloud to Moorhead. The majority of these plantings are in the Minnesota River Valley, but are well beyond the native range of the

species. A few vigorous and productive sweet chestnut trees have been located in Winona and Houston counties. Successful plantings of butternuts have been located along the Minnesota River Valley to Swift and Lac Qui Parle counties. The butternut often suffers from sunscald on the prairies, so should be given some protection when planted in the western part of the state. A few new experimental plantings have been developed during the year with black walnut, sweet chestnut, and Japanese walnut (*Juglans sieboldiana* var. *cordiformis*). Sweet chestnuts, filberts, and pecans have killed to the ground at University Farm and at the trial planting a few miles south in the Mississippi Valley. The condition of these nuts in the plantings farther south has not been determined. The hickory shows a high mortality, due largely to the difficulty in transplanting the long tap-root. Trees that survive transplanting give promise of vigorous growth.

SECTION OF FRUIT BREEDING

Breeding for hardiness in fruits.—This project was carried forward as in previous seasons. Special attention was given to crosses with the blackberry, raspberry, apple, grape, and plum. Satisfactory germination of the seed in the crosses has been obtained. The parentage in these crosses was carefully selected on one hand for hardiness and on the other for quality of fruit for fruit characters. Crosses were made in the greenhouse and under tent, both methods proving satisfactory under the conditions prevailing last season. The hardy Canadian raspberries and the hardy blackberries from Cloquet and Aitkin have been used as pollen parents. The winter was mild for all fruits except raspberries and strawberries. Records were taken on the killing in the raspberries this spring. Considerable attention has also been given to the cytological and physical phases of hardiness with particular reference to the plum. A report on this work is in progress.

Inheritance of fruit characters.—The studies on the inheritance of characters were continued and checked again in the plum material available. An analysis was also made of the characteristics of open-pollinated seedlings of the Malinda apple. A report on the inheritance of characters and the dropping of fruits in the plum is under preparation.

Sterility in fruits.—The sterility studies have been confined primarily to the plum and the apple with preliminary observations on the setting of fruit in the currant. Records of the setting of the controlled crosses in the greenhouse and under the tent have been taken again. These data give an index of the relative efficiency of the different varieties as pollenizers. The investigations on the rate of pollen tube growth have been checked under the conditions of another season. Preliminary observations for two seasons indicate that in the currant there is great variability in the setting at the tip of the clusters in the different varieties.

SECTION OF VEGETABLE GARDENING

Breeding and selection of vegetables.—Several distinct strains of Alaska pea and Refugee bean have been isolated and are being tested with the aim of obtaining superior canning types.

F₁ and F₂ plants of several crosses between the White Spine cucumber and English varieties were grown in the greenhouse and a study of the inheritance of fruit characters was started. The results obtained indicate that the characters studied are inherited independently and that they segregate in the F₂ generation according to mendelian laws. Several desirable commercial types have been noted among the F plants.

The study of the first generation hybrids of tomatoes has been completed, the data indicating that in some hybrids the plants fruit earlier and yield a larger crop than either of the parent varieties.

The continued self-fertilization of the Hubbard squash for four generations has resulted in the isolation of at least fifteen distinct types, which appear to be breeding true. These fifteen strains and several first generation hybrids have been tested for yield and other economic characters, with several lots of commercial strains used as checks. Results show that some of the inbred strains possess remarkable vigor, outyielding the strains obtained from commercial seedsmen. The first generation hybrids averaged slightly higher in yield than the higher yielding parent. As a matter of technic in conducting these yield tests, observations were made on the factors affecting the setting of fruit, the effect of the size of seed on the vigor of the vine, and the effect of competition between plants on the yield.

There is considerable variation in the weight of the individual seeds in a squash, and there is a positive correlation between the weight of seed planted and the size of the seedling, which is carried through, finally affecting the yield. Under conditions at University Farm, the squash plant is competing with adjacent plants when planted 6 by 10 feet apart; and when a plant is injured or otherwise weakened, the adjacent plants show a definite increase in yield.

The inheritance of fruit characters of economic importance, such as thickness of the edible portion; maturity; size, shape, color, and general appearance of the fruits, is being carefully studied.

From the fifteen pure types, two appear to be of much promise, and a limited number of seeds have been distributed for wider trials. One of these is a small squash, very early maturing, particularly adapted to the home garden; the other is being sent out as a commercial type, having good quality, uniformity, and high yield.

Potato investigations.—The seed-piece and vine studies begun in 1917 show that the number of tubers set per hill is directly related to the number of stalks per hill, and that the number of stalks per hill

is determined by the size of the seed piece planted, and by storage conditions as they affect the rest period of the tubers.

A study of the influence of soil and climatic conditions on tuber type in the Early Ohio variety, indicates that distinctive types are developed under varying soil and climatic conditions. All lots when grown under specific growth conditions develop tubers of a similar character regardless of the original type exhibited by the parent stock.

Considerable progress has been made in the degeneracy studies. The characteristics indicative of running out of potato varieties at University Farm have been shown by controlled experiments in the greenhouse to be transmissible.

Field experiments show that when insects are excluded from healthy stock by the use of cheese-cloth screens or when healthy stock is isolated from diseased stock plots, no degeneracy is apparent in the progeny. The complete results of the work on "running out" of potatoes have been prepared for publication in cooperation with the Division of Plant Pathology and Botany.

SECTION OF LANDSCAPE GARDENING AND FLORICULTURE

Practically all shrubs and herbaceous perennials came through the winter of 1919-20 in excellent condition. The dahlia trial did not result in anything of special value, as the hot dry weather stunted the flowers and very few recovered in time for fall flowering. A few of the varieties seemed to stand the drouth better than others and these are being watched again this season.

Of the hedges, *Cotoneaster acutifolia* was among the best. It is also excellent for foundation and group planting. *Viburnum lantana* and *Crataegus* have again especially demonstrated their value as clipped hedges.

About a dozen of the best peony seedlings have been selected and are being propagated this season. Two or three hundred more will be planted on the campus. A trial ground of peony and iris has been established by the Northwestern Peony and Iris Society. New and old varieties will be planted this fall for demonstration and trial purposes.

Seed of shrubs and perennials were collected last fall and planted this spring and many of them are growing nicely.

About seventy-five varieties of chrysanthemum were flowered in the greenhouse. A small trial of flowering bulbs was also made, largely for demonstration purposes.

DIVISION OF PLANT PATHOLOGY AND BOTANY

E. M. FREEMAN, Chief

Plant disease survey.—More detailed information on the seriousness and distribution of plant disease was obtained in 1919 than in any

previous year. About eight hundred samples of diseased tissues of cultivated and wild plants were collected. The most serious diseases were black stem rust of wheat and wheat scab. These two diseases seriously reduced the yield of wheat. A seedling blight of wheat and rye also was widespread and apparently somewhat destructive.

Rusts of cereals.—The isolation and identification of biologic forms of black stem rust on varieties of wheat was continued and about twenty-five distinct forms were obtained. A study of the behavior of wheat crosses to two biologic forms was made and it was clearly shown that forms can be obtained by hybridization which are resistant to at least two biologic forms when neither of the parents is resistant to both. This gives some hope that it will be possible eventually to breed wheats resistant to several biologic forms.

An extensive study of the epidemiology of cereal rusts was continued in cooperation with the Bureau of Plant Industry and it has been shown quite clearly that the principal source of rust in Minnesota is the common barberry. This furnishes additional evidence of the necessity of vigorously prosecuting the barberry eradication campaign.

Further work was done on rust resistance of certain selections of timothy and it seems quite probable that it will be possible to develop good resistant strains.

Work on the nature of resistance to stem rust was continued and some valuable data have been obtained.

The barberry eradication campaign was continued on a large scale. About fifty thousand bushes were eradicated, and additional information was obtained on the distribution of rust-susceptible barberries on farms. It was discovered that there were a great many escaped barberry bushes in the state. Every possible effort is being made to eradicate them.

Cereal and forage crop diseases.—A study of the resistance to smut of different varieties and selections of corn was begun. Valuable preliminary results were obtained.

The work on the development of wilt-resistant flax was continued, and it was demonstrated that these selections retained their resistance at Waseca and at Crookston. The amount of seed was increased and it should be possible, if conditions this year are favorable, to distribute a limited amount of this seed next year. It was shown that flax does not lose its resistance to wilt by being grown in clean soil a year.

A careful study was made of various imperfect fungi causing diseases of wheat, rye, and other cereals. It was shown that a species of *Helminthosporium* is responsible for a seedling blight of wheat and rye. This disease is capable of causing serious losses, since it affects not only the seedling plants but also the mature plants. The etiology of the disease has been carefully worked out and the results have been submitted for publication.

Scab of wheat and other cereals was investigated and the temperature relations of the causal organisms have been worked out. Much additional information also has been obtained on the host range of the causal organism. It has been shown that the pathogenicity of various strains of the organism may vary. It has also been demonstrated that the wheat scab organism attacks several wild grasses and a number of forage plants and vegetables. These facts point clearly to the necessity of developing resistant varieties.

About seven hundred and fifty varieties and selections of wheat were tested for resistance to bunt. There was considerable difference in the relative susceptibility of these varieties, and this work will be continued in the hope of getting a good commercial variety which is resistant to bunt.

Potato and garden truck diseases.—The long-time spraying experiments on potatoes were continued, and it was shown that spraying with bordeaux mixture is very valuable over a period of years, even in the absence of late blight.

The work on potato mosaic, leaf roll, curly dwarf, and related diseases has shown clearly that mosaic and leaf roll are infectious. This makes it necessary to practice good seed plot methods in order to control the losses from these diseases.

Fruit diseases.—The etiology of the gray bark disease of raspberries has been worked out. Preliminary control experiments were also made, but it is not yet possible to make definite statements regarding the possibility of reducing losses by spraying. The comparative value of dusting and spraying fruit trees in Minnesota was tested. Excellent results were obtained by dusting. Since this method of controlling fruit diseases is simpler than the application of liquid sprays, it would seem that the substitution of dusting for spraying probably can be recommended if future results are as definite as those so far obtained.

Seed studies.—Seeds of sweet clover spotted with purple, as in yellow sweet clover seed, and heretofore considered as yellow sweet clover have been found to be seeds of white sweet clover (*Melilotus alba*). This discovery makes it possible to make more accurate tests of sweet clover seed and to give more reliable information to farmers and dealers as to the purity of their seed.

Improved methods of testing lettuce seed have been worked out. Preliminary soaking may be eliminated and seed may be germinated on blotters, making the counting of sprouts more rapid.

Subproject: *Seed cases.*—The demand for seed cases still continues.

Subproject: *Seed testing.*—The seed companies were this year limited as to the number of samples that may be sent to the Seed Laboratory within a certain time. The limit was placed at 15 purity and 40 germination tests per month. As a result the number of samples

decreased to approximately eight thousand. This limit may be further lowered and then a more definite campaign for seed testing may be carried on among the farmers.

Weeds. Subproject: *Sow thistle work.*—There are two distinct varieties of perennial sow thistle in Clay County. One has a smooth stem and grows vigorously and is much more widely distributed than the other. It seems the more serious of the two. Most of the work was with this variety. The other has gland hairs on the peduncles and flower bracts. It is much smaller and but little spread throughout the county. It bears less seed than the former and does not take so complete control of the land. Manitoba also notes two varieties.

Clay County is at about the southern border of the general distribution of this plant. Practically every farm has some infestation and several are completely infested.

Clean cultivation has in several instances killed out this thistle. Both thoro cultivation in a cultivated crop and bare fallow from July 1 to September 1 have cleaned out fields. Cattle and sheep prevent its seeding in open pastures. Spraying with either sodium arsenite or fuel oil is not satisfactory. It is expensive and lacks thoroness. Covering with straw to a depth of from 14 to 18 inches proved very satisfactory. Covering with tar paper was successful but expensive. Frequent hoeing throughout July and August is to be recommended for small areas in crops which can not very well be handled otherwise.

DIVISION OF POULTRY HUSBANDRY

A. C. SMITH, Chief

The poultry division has continued investigations concerning the efficiency of different commercial chick mashes and feeds as to growth and mortality. These investigations were confined to two classes of ground mixed feeds which depend either on buttermilk or beef scraps for their animal protein supply. Study of the cost of producing chicks of different ages has also been continued. Further work in both lines is planned. Feeding rations for winter layers and young chicks have been compiled for distribution.

The division is also cooperating with the section of animal nutrition and the Department of Anatomy, Medical School, in supplying materials and equipment for investigations carried on in those departments.

DIVISION OF SOILS

F. J. ALWAY, Chief

Peat soils.—Work is now well under way at all three of the experimental tracts for which provision was made by the legislature of 1917.

At Golden Valley a great variety of crops in 1919 showed the same marked response to phosphate, manure, and burning as in 1918. As little as 50 pounds per acre of acid phosphate caused a very marked improvement, altho from 200 to 400 pounds appears more profitable. Neither rock phosphate nor bone meal approached acid phosphate in effectiveness. As in the first season, potash, either alone or in combination with phosphate, appears to be without beneficial effect. A disastrous flood early in July ruined practically all crops for many miles around, including most of those on the experimental fields. Only winter rye and part of the hay crops were harvested.

At the northeastern tract, at Fens, good yields of winter rye, hay, and root crops were obtained by the use of phosphate, manure, or burning, while potash continued to show no response. While the initial chemical requirement at Fens is similar to that at Golden Valley, the problem of reclamation is very different, the peat being so infested with stumps and logs as to make very expensive the preparation of a seedbed free from woody fragments. To meet this difficulty experiments have been started in the establishment of pastures on the wild bog without plowing, using only phosphate fertilizer. Experiments have also been initiated on the effect of maintaining the water level at different depths below the surface.

At Coon Creek excellent yields of hay and potatoes were secured in 1918 and heavy yields of hay are already assured for this season. The soil on this tract requires both phosphate and potash, phosphate alone proving of no benefit; altho potash alone causes greatly increased yields of some crops.

The coöperative experiments on the peat lands of the northwestern counties, arranged with the respective farm bureaus, showed that most of the soils dealt with, like those at Golden Valley, have an initial chemical requirement of phosphate only, which can be satisfied by either acid phosphate or stable manure. The July floods drowned out most of the crops on these plots, making it impossible to obtain data on yield.

Sandy soils.—An appropriation of \$2,500 was made by the 1919 legislature to provide for field experiments for two years on sandy soils. A site for the principal experiments has been provided by a long-time lease of a field adjacent to the Coon Creek peat experimental tract, thus making it possible to operate both with the same equipment. Experiments have been started on the use of lime, the various fertilizer constituents, peat, and stable manure, employing as trial crops legumes,

potatoes, corn, and rye. In coöperation with the owners of five fields of a much lighter sand, soybeans and alfalfa are being tried with and without lime.

Fertilizer experiments.—The experiments with phosphates, both alone and in combination with stable manure, at University Farm and the various substations, have been continued, with results in general similar to those described in the previous report. At Crookston, however, for the first time, a distinct and unmistakable increase in yield from the use of phosphates was shown, this being with the second cutting of red clover. At the same place potash has continued without effect, while nitrogen has shown little benefit with potatoes and corn.

The coöperative experiments with acid phosphate in the southeastern counties, carried on for three years, have been concluded.

The experiments with sugar beets, carried on in the south central part of the state in 1919 in coöperation with the Minnesota Sugar Company, showed little effect from either phosphate, potash, nitrogen, or any of the various combinations of these.

Experiments with acid phosphate on the mineral soils of twenty farms in Pennington County have been started in coöperation with the farm bureau of the county.

In coöperation with the American Agricultural Chemical Company, a complete fertilizer, applied at different rates, is being tried in Hennepin, Anoka, Sherburne, Milaca, Isanti, Wadena, and Clay counties, using chiefly potatoes as the trial crop.

Soils of the different drift sheets.—The soil survey of Stevens County has been completed and the report is in process of publication. The chemical and physical study of the soils of the different types mapped in both Stevens and Anoka counties is nearly complete.

Glacial soils of the Gray Drift.—This project has been completed and the results are ready for publication.

Movement of water in soils.—Laboratory and field studies on this project have been resumed.

DIVISION OF VETERINARY MEDICINE

C. P. FITCH, Chief

The work of this division has progressed satisfactorily throughout the year. The largest amount of time has been devoted to research work on the complex problem of bovine infectious abortion. The number of specimens received for laboratory diagnosis has markedly increased and this part of the activities of the division is assuming great importance. This latter work is in coöperation with the Live Stock Sanitary Board.

SECTION OF ANIMAL PATHOLOGY AND BACTERIOLOGY

Bovine infectious abortion.—The experimental herd now consists of sixteen cattle and eleven calves. All the females have passed through one pregnancy and nearly all are in calf again. The results so far obtained with the various biological products used to control this disease, indicate that they are of little value and that the living virus used so widely in England may even be detrimental, in that it renders the animal sterile. As was pointed out last year, it must be kept clearly in mind that research on this disease must be carried on through a series of years before one is justified in drawing positive conclusions in regard to the value of these biological immunizing agents. The work is being continued and more data compiled. Further work on the blood tests adds evidence to support the statements made in the preliminary report, that these tests are of little value in indicating whether an animal has aborted or will abort. They do indicate the amount of herd infection. The data collected during the last year add more evidence to support the statement that the blood of the young calf and the dam may or may not have the same agglutination titre. This is contrary to the work of Rettger. The special bulletin on abortion disease was again revised, owing to the exhaustion of the supply, and short accounts of abortion disease among swine and sheep were included. Work was started on the bacterial flora of the genital tract of cattle. The study of the various organisms which cause inflammation of the female genital organs was also begun. Experiments to determine whether the bull can be artificially infected with *Bact. abortus* (Bang) have been undertaken. The relation of the bull to the distribution of the virus of bovine infectious abortion is still not clearly demonstrated. Several publications are now being prepared on these phases of this disease. A paper on the diagnosis of this infection was printed in February.

Contagious abortion of mares and pyemic arthritis of foals.—The study of the biology of *B. abortivo equinus* was completed and the paper accepted for publication. The survey by means of the blood tests was continued. As was pointed out last year, we have failed to find *B. abortivo equinus* among the breeding stock at University Farm. In every instance where an organism has been isolated from a case of abortion or pyemic arthritis, it has been a streptococcus. The work of several foreign investigators (M'Fadyean, Magnussen) confirms the statement that *B. abortivo equinus* is not always the cause of these diseases of mares and foals. The results of their work bear out the experience at University Farm. The use of anti-streptococcic serum has been continued with most gratifying results. We have not had a fatal case of arthritis in foals since we began to employ it. One mare which has aborted for two years previously is now carrying her foal in the tenth month of pregnancy. She has been immunized with anti-

streptococcic serum. Four abortions have occurred this year among the mares, and in each case carefully prepared cultures from the fetus have remained sterile. One of these cases can be explained by a mechanical cause. The remaining three are still undetermined. The results which we have so far obtained in the investigation of this infection agree with those of the foreign investigators but are not in accord with the published accounts of the researches on this disease in this country.

Obscure infectious diseases.—During the year, 551 specimens were examined. This is an increase of 22 per cent. Among the more important investigations are anthrax; swine diseases; parasitic infestations, especially of sheep and horses; and diseases of poultry. The first outbreak of anthrax in Minnesota of any importance occurred in the vicinity of Montevideo. In coöperation with the Live Stock Sanitary Board, one of the staff of this division established a temporary laboratory in the infected district in order to render quick and efficient service in the diagnosis of suspected cases. Several severe outbreaks of intestinal parasitism of horses have been found, and a careful study of the nematodes is being made. An outbreak of *uncinariasis* in young cattle was observed. So far as we know this is the first time this disease has been reported in Minnesota. The presence of sarcoptic mange in cattle was reported also for the first time. Tuberculosis in poultry continues to be a most serious disease. Experiments are in progress to determine the value of tuberculin testing in the control of this malady, also experiments to determine methods of dissemination. A disease of geese has been recognized for the first time in this country.

This work is of the greatest importance, for it not only aids in the suppression of disease among the herds of the state but it furnishes the division with a constant and exceedingly valuable source of material for investigation. Fifty-six trips have been made for the Live Stock Sanitary Board in order to investigate cases of obscure disease. Two publications have been submitted as a result of this work and several others are being prepared.

SECTION OF VETERINARY PHYSIOLOGY

The work of this section has been resumed and one project on the causes of the normal variations of the temperature of cattle has been submitted. The importance of this work is very apparent in the thermal method of testing for tuberculosis. Data are being accumulated by the use of the abortion experimental herd, and the work will be continued during the coming year.

SECTION OF VETERINARY MEDICINE

The pathology of sterility in bovine infectious abortion.—The study of sterility has been vigorously pursued. This subject is of vast importance to the breeders of purebred cattle and they are coöperating in

every possible way. A large number of field trips have been made for the purpose of advising as to the prevention of abortion disease and sterility, and to determine the various pathological conditions affecting the genital organs of breeding cattle of all breeds. In many instances we have been able to restore to breeding condition, cows that were thought to be hopelessly sterile. Other cows suffering with certain changes which were thought to be curable gradually became worse and had to be sold for slaughter. Cervicitis has been given special attention and is frequently the cause of either temporary or permanent sterility. The exudate occurring in cervicitis varies from a thin mucous discharge containing particles of pus to a thick adhesive mass that may easily be mistaken for the normal mucous plug of pregnancy. The *corpus luteum*, which quite often fails to disappear following parturition, becomes pathologic, and mechanically interferes with ovulation. It may inhibit ovulation also through an internal secretion. In numerous cases wherein a persistent *corpus luteum* has been dislodged from one ovary, ovulation and fertilization occurred from the opposite ovary. Mucoïd degeneration of the uterine mucosa has been studied, also cystic changes of the uterus, fallopian tubes, and ovaries. In cystic degeneration of the uterus, the cysts have been found to occur mainly within the uterine glands.

Infectious white scours and calf pneumonia.—Investigations of this common and often fatal disease of calves were continued. Anti-white scours serum has been used extensively as both a preventive and a curative agent. Numerous calves injected with large doses of serum at birth have developed the disease from a few days to eight weeks later. Large and frequent doses of serum administered to calves already ill are beneficial but should not be recommended too highly. Pneumonia may occur independently of scours, but both frequently occur at the same time. In cases of massive lung lesions, the employment of serum is of little benefit. We have been able in several outbreaks of this affection to isolate a streptococcus as well as various strains of *B. coli*.

FARM PRACTICE

A total of 638 cases were presented in the clinic for treatment. Several of these were of great interest and the data collected have been filed for future reference and publication. One article has already been written and submitted. All the cows owned by the University are examined at frequent intervals in order to prevent the development of chronic cases of sterility and to maintain the breeding efficiency of these animals at a high standard. The breeding mares are examined to determine the condition of the genital organs, and treatment is applied to relieve any diseased condition found. The mares are also examined after breeding to determine pregnancy.

SECTION OF VETERINARY BIOLOGICAL PRODUCTS

Production and distribution of anti-hog cholera serum.—To produce serum in such quantities as was necessary to supply the demands of the state was deemed inadvisable under present conditions and was therefore discontinued. Serum is purchased on the open market and retested for potency before distribution. A supply of clear sterile serum was subjected to severe tests and was found to be highly potent and reliable. We believe that a clear sterile serum is a step in the right direction and advise its general use.

Lesions characteristic of hog cholera in immune carcasses.—Swine were immunized by the serum-virus method when small and at time of slaughter the available viscera were examined. Many of these showed at least one or two lesions that are characteristic of cholera. This work will be continued.

Gross and microscopical lesions of hog cholera.—In this work, complete autopsy records have been kept on 659 cases. The incubative periods varied so that the pigs were in a moribund state from 5 to 12 days. The intensity or severity of the lesions did not seem to be increased in the same ratio as the length of time the animal was sick. Changes in the lymphatic system were recognized in a greater percentage of the cases than in any other tissue, while the lungs, bladder, and larynx showed no changes in a large percentage of cases.

Longevity of hog cholera virus.—The work has been completed, the results compiled and published. The results indicate that the virus remains virulent as long as three years if phenolized and kept at a low temperature.

Special biological products.—During the year 38,000 doses of hemorrhagic septicemia bacterin have been prepared and distributed. This work is done in cooperation with the State Live Stock Sanitary Board. There were distributed 2,245 doses of B. A. I. blackleg vaccine.

SECTION OF LIVESTOCK SANITATION

The work of this section is divided into two groups (1) A regulatory project relating to work with the State Live Stock Sanitary Board and the Minnesota Stallion Registration Board. (2) Tuberculin test research work.

This section has continued cooperation with these two boards through board memberships. There has been a persistent effort to promote progressive but safe and rational control work with various infectious diseases of domestic animals, especially tuberculosis and hog cholera.

Live Stock Sanitary Board work.—Tuberculosis-free accredited herd work, formerly a special project in this section, made very rapid

progress. This work is now done jointly by the State Live Stock Sanitary Board and the Federal Bureau of Animal Industry. Minnesota has now about five hundred fully accredited herds as against 146 a year ago, and 880 other herds which have passed one clean test, most of which will soon become accredited, as against 350 a year ago. Between three and four hundred other herds were tested and gave some reactions. The total for this year is about seventeen hundred herds. Livestock sanitary conditions on the whole were favorable. A local but serious outbreak of anthrax centered around Montevideo. Unusual precautions have been taken to prevent recurrence.

Hog cholera prevalence and losses were comparatively light, although early in the year the situation was threatening.

Minnesota stallion board.—The head of this section has continued in the same relation and work with the Minnesota Stallion Registration Board as heretofore. In this he has done field work as soundness expert and referee in cases of differing opinions between examining veterinarians. Licenses were refused or revoked for 23 unsound stallions.

Tuberculin research.—The tuberculosis control work with the seven University herds has continued in the care of this section and our herds appear to be free or practically free from tuberculosis.

Tuberculin test research work has continued to cover especially the relative accuracy of the intradermal, ophthalmic, and thermal tests and the relative desirability of several possible combinations of these tests. Tuberculin tests other than the standard thermal are becoming officially recognized by the federal government and several states. There appears to be reasonable question concerning the desirability of such present recognition, and it seems highly important that much accurate information concerning these tests be made available as rapidly as possible.

During the year these questions were studied in connection with 222 tests thermal only, 75 intradermal and thermal; 166 ophthalmic and thermal; 18 intradermal and ophthalmic; 122 intradermal, ophthalmic, and thermal; 9 intradermal; 26 ophthalmic only, a total of 638, in addition to smaller numbers of other combinations and studies.

The importance of using combined or follow-up tests for most accurate work is becoming very apparent. No objection has been found to combination of intradermal and thermal. The value of the ophthalmic test has appeared to be somewhat impaired by the fact that an important number of eye disturbances occur among non-tuberculous and untreated cattle. These disturbances resemble ophthalmic reactions and are therefore liable to discredit sound cattle as possibly tuberculous when such non-specific disturbances happen to occur in connection with a test where the ophthalmic method is used.

WORK OF THE SUBSTATIONS

NORTHWEST EXPERIMENT STATION, CROOKSTON

C. G. SELVIG, Superintendent

GENERAL CONDITIONS

The season of 1919 was not favorable for work in cereal crops and potatoes on account of the damage from the heavy rains followed by extremely hot weather. While the total precipitation for 1919 followed closely the average for this section of the state, an unusual amount of rain fell in July, a total of 8.83 inches. Of this, 6.5 inches fell on July 2. This flood, followed by bright sultry weather, caused considerable damage to the growing crops. Spring work began about ten days later than usual, the first disking being done by April 16. Most of the seeding, however, was completed before May 1. Grain crops matured about ten days earlier than usual owing to the hot weather of early summer. Rust was prevalent, attacking particularly Bluestem and Marquis wheat, and greatly reduced the yields. Harvesting was completed by August 28.

The season was one of the longest on record, with the latest killing frost in the spring on May 1 and the earliest fall frost on September 25. It was very favorable for corn and potatoes, medium red clover, alfalfa, and sweet clover, all of which yielded well.

DRAINAGE

The unprecedented rainfall of 6.5 inches on July 2 caused the outlet ditch through which the water from the station fields flows to overflow its banks. This made the station ditches ineffective; they were filled with standing water for several days. This in turn filled the tile lines and damaged them seriously. Where the tile outlets were open a good flow was maintained for about two weeks. There is no doubt that the tile lines gave good service even tho underdrainage was slow.

WORK WITH FARMERS

The pure seed work was well supported in every county. There were 175 coöperators in 1919. This was carried on largely in coöperation with the farm bureaus of the district. Minnesota No. 470 wheat made the best record. The annual pure seed exhibit held in connection with the Northwest School Farmers' Week has been valuable in stimulating interest in pure seed among the farmers.

The home project work is growing in favor, in extent, and in results each year. It carries the results of the experimental work to the homes of the students attending the Northwest School of Agriculture and in that way reaches a large number of farmers in the different counties of this section.

Other work with farmers includes personal visits by members of the staff to a large number of farms annually, conferences at the station, extensive correspondence, coöperation in boys' and girls' club work, and meetings. The number of appointments filled by the superintendent and staff during the last year is 181.

The annual Northwest Farmers' Week meetings have been a strong influence in this part of the state. The Red River Valley Livestock Association has sales and exhibit buildings valued at \$75,000, where hundreds of purebred animals are exhibited. The sale held last February aggregated more than \$100,000. The superintendent of the station is president and the livestock man secretary of this association, which has a membership of more than 1,400.

AGRONOMY SECTION

Cultural methods with farm crops. Subproject: *Rate of seeding wheat, oats, and barley.*—The most commonly used rate of 5 pecks of wheat per acre gave the highest yield, with an average of 27.2 bushels per acre. Low yields of oats were obtained in 1919, largely because the cold wet weather during the early part of the season caused a thin stand. The work with barley was begun in 1919. On account of the damage caused by the flood water the yields are not reliable, but the 8-peck rate gave the highest yield.

Varietal tests of farm crops.—The work with varieties of farm crops is very similar to that of 1918.

Wheat, barley, and oats.—From the yields of wheat in variety trials to date, it appears clear that Mindum, Minnesota No. 470, a selection from Minnesota No. 951, is the best durum wheat, and Marquis the best common wheat that can be recommended for the Red River Valley. In years such as 1916 and 1919, with the black stem rust epidemic severe, Mindum out-yielded Marquis, and in years such as 1917 and 1918, with little trouble from black stem rust, the two varieties yielded equally well. Iowa No. 105 and No. 103, early varieties of oats, made high yields in comparison with the other varieties. Kherson and other early varieties also showed promise. Akers barley, a six-rowed variety, continued to make a high yield. Minsturdi, Beardless, Imp. Manchuria, and A. O. C. No. 21 were highest yielders.

Flax and peas.—Minnesota No. 177 flax gave the highest yield. Both home-grown and imported fibers gave consistent yields. Amroati and Gold Vine field peas gave not only the highest yield of seed but also the best growth of vine.

Forage crops and corn.—Eight varieties of soybeans showed good possibilities, with fine forage, but were killed by frost too early for a check on seed production. In 1919 varietal tests were made of fourteen different varieties of what may be considered northern Minnesota corn.

These selections include some of the best yielding flints, Minnesota No. 23, Northwestern Dent, Minnesota No. 13, and White Dent. The season was very favorable for corn and all varieties matured fully with the exception of the large strain of White Dent. One of the striking results of the corn varietal tests was that selections made from local varieties matured from six to ten days earlier than those from seed supplied from University Farm. The yields varied from 26 to 79 bushels, the highest being Northwestern Dent.

Nursery varieties.—Extensive increase tests of wheat, oats, and barley were conducted in cooperation with the Central station. The result in the rod-row test was very similar to that on the larger test plots—the heavy floods and black rust preventing any appearance of new selections.

Alfalfa and grasses.—A new series of grasses and grass-mixture plots was started this year. In the alfalfa test which was started in 1917, Disco 38 showed the thickest and finest growth, gave the highest yield, 11,065 pounds per acre, and showed the greatest promise for seed production. The Grimm variety showed promise from the standpoint of yield, but the stems were very coarse and woody. A new series of alfalfa tests will be started in 1920 as will a new series of grass variety tests.

Crop rotations.—The work with crop rotations was continued. The average yield of wheat in the 3-year, 5-year, and 7-year rotations is practically the same. Wheat grown continuously yielded 5.6 bushels less on the average during the 8-year period than wheat grown in a rotation; while wheat grown continuously with 6 pounds of clover yielded 7.2 bushels less on the average during the 8-year period than wheat grown in a rotation. The oats in the 7-year rotation averaged 9 bushels more during the 8-year period than in the 5-year rotation. Barley in the 7-year rotation maintained an average of 33.9 bushels; and flax in the same rotation, of 15.4 bushels. Detailed results are given in the station report.

Soil fertility and soil management experiments.—In 1919 small grains were all very badly damaged in the early part of the season by the heavy rains and in the latter part by hot, dry weather. In no particular case was there a striking increase by the use of phosphate fertilizer. In some cases with each of the crops of wheat, corn, oats, and field peas, the no-treatment plots yielded fully as high as those that received treatment. Striking results for 1919 were the fine stand of clover on Series V, using wheat as a nurse crop, and the stand of mature Minnesota No. 23 corn.

Complete fertilizer experiment.—In the complete fertilizer experiment the 3-year rotation includes barley, clover, and a cultivated crop. In this rotation all the plots receive an application of manure every

three years and the benefit of clover stubble whenever a stand is secured. The second crop of clover in 1919 showed very marked benefit from the phosphate application. This is the first crop that has shown really distinct benefit from any fertilizer since the experiment was started, in 1914.

Rate of manuring.—The highest yields of both wheat and corn in 1919 resulted from the application of 16 tons of manure, yet the differences in yield from different rates of application were not very marked.

Straw utilization.—Results for the first two years indicate little effect from either straw or ash. Corn showed an increase of grain but a decrease of stover where the two tons of straw were burned. The yields were not strikingly different.

Fallow and crop sequence.—The object of this experiment is to determine the value of clean summer fallow for wheat, oats, and barley as well as the most desirable sequence of these three crops with respect to its use. A series has not yet been completed.

HORTICULTURAL SECTION

Fruit investigations.—Practically all of the standard hardier sorts of apples have failed in the test plots. A few Hibernial trees of weak growth remain. Virginia, Transcendent, and Arctic crabs remain and for the most part are making good growth. A few fruits were gathered from Virginia, Arctic, and Early Strawberry in 1919. Many of the newer trees of the same varieties also set fruit this spring.

The grass plots in the cultural test of apples and crabs had to be replowed in the spring of 1920 because of the germination of sweet clover seed which had apparently blown in from adjacent sweet clover plots. These grass plots will be reseeded as soon as the clover is eradicated.

Rabbits and field mice did considerable damage to fruit trees during the winter of 1919-20. Many trees were girdled and smaller branches were pruned by the rabbits above the snow cover. The early fall of snow before freezing weather made an excellent ground cover and as a result most fruits came through the winter in good condition. Three of the standard varieties of plums in test fruited, namely DeSota, Surprise, and Compass cherry. Many of the plums transplanted from a nursery row in the old farm garden have proved to be valuable seedlings of unnamed varieties. Unfortunately no data concerning these trees were found on record. The following plum seedlings yielded good crops in 1919: 2A, 3A, 6A, 7A, 11A, and 12A. The season was sufficiently prolonged and advanced for all varieties to ripen before frost.

One hundred sand cherry seedlings were planted in the nursery rows in 1919. A good stand was obtained.

The only strawberry varieties in the trial plots during 1919 were seedlings, planted in coöperation with the state fruit breeding farm. Nine numbered seedlings planted in 1918 were in the test. Five varieties fruited in 1919. Of these 389, 589, and 835 are apparently as good as most of the standard bearing sorts commonly grown in this section. No. 842 was practically the only undesirable variety of the lot. No. 754 produced the largest fruit but was a shy bearer. Strawberries came through the winter in good condition and have set a good crop.

All the varieties of raspberries remaining in the variety test plot came through the winter in excellent condition and considerable fruit was gathered in 1919. Sunbeam came through in best condition and produced a good crop of fruit. The fruit, however, is not of first quality. The varieties that fruited are Turner, King, and Cuthbert. Gregg black raspberries fruited in quantity last year for the first time in seven years. This variety does not, however, produce as abundantly as any of the above-named red sorts. In the spring of 1920, fifty plants each of King, Latham, and Bullhead, representing the three degrees of hardiness, were planted in coöperation with the Division of Horticulture, University Farm.

Good crops of gooseberries and currants were harvested. Most of the currants are old enough now to produce profitable crops. The varieties that fruited are Perfection, Long Bunch Holland, and Red Cross. Houghton and Carrie gooseberries yielded good crops. Seventy numbered seedling gooseberries received from the state fruit breeding farm were planted in 1920. A good stand was obtained.

Beta, Campbell's Early, and Janesville grapes each set a few clusters of fruit in 1919. Thirty numbered varieties of grapes from the state fruit breeding farm were planted in 1920.

Tree planting investigations.—Tree and shrub planting in 1920 consisted of the planting of ornamental trees and shrubs on the campus and around the cottages and the setting of evergreen seedlings, willow, and green ash trees in the windbreaks.

Garden crop investigations.—In many ways the season of 1919 was very favorable for garden crops. The long frost-free period with relatively high temperatures in early summer hastened all seed and leaf crops and enabled many of the more tender half-hardy crops such as vine crops, tomatoes, and beans, to produce good yields. Garden roots crops such as beets, carrots, and parsnips, made good yields and were of excellent quality. While normal yields were produced by the majority of garden crops, the following produced outstanding yields:

Beans.—M. A. C. Robust, a small white navy bean, yielded 34.66 bushels per acre and Great Northern, a white kidney bean, 38.8 bushels.

Cucumbers.—Extra heavy yields were obtained from all varieties. Long Green gave the highest yield of the nine varieties in the test, yielding 578.4 bushels per acre, with Early Frame second, yielding 529 bushels per acre.

Sweet corn.—Golden Bantam ranked first in yield of the five varieties in test, yielding 132.5 bushels of roasting ears per acre.

Squash.—All winter varieties of squash produced well. Green Hubbard, as in former years, ranked first of the winter types, with Golden Hubbard second. Boston Marrow, an autumn squash, gave the highest total yield, producing 5,860 pounds per acre.

Tomatoes.—The earlier types of tomatoes such as Earliana, June Pink, Bonnie Best, and Early Minnesota, were most satisfactory, yielding 307, 98, 105, and 192 bushels, respectively. Stone, an excellent late variety, yielded well, owing to the extremely long season. In ordinary years this variety ripens only a small percentage of its crop.

Root crops.—Fair to good yields were obtained from the mangel and sugar beet varieties in test. Giant Sugar Beet mangel ranked highest in yield, producing 21.13 tons per acre, followed in order by Danish Sludstrup and Eckendorf. The sugar beet varieties yielded as follows: Vilmorin Elite, 10 tons; Klein Wanzlebener Elite, 11.38 tons.

Rutabagas.—Carter's Hardy Swede gave the highest yield of the six varieties of rutabagas in test. Prizewinner and American Purpletop produced the most satisfactory crops for table use, yielding 383.3 and 375 bushels per acre.

Turnips.—Amber Globe Green Top gave the highest yield, averaging 325 bushels per acre. Purpletop Yellow, in test for the first time, seems to be a variety of great merit.

Potato investigations.—Potatoes in the different experimental projects did not produce uniformly good yields in 1919, owing primarily to excessive rainfall and flood conditions. Potato beetles were unusually common, owing probably to the mild winter of 1918-19. Five and six field sprayings were necessary to control and keep them in check. The late varieties withstand midsummer floods much better than the early sorts. They were retarded by the flood conditions, but produced profitable crops in most cases, chiefly because the frost-free period was prolonged into late September.

Seed treatment for potato tuber diseases.—The copper sulphate treatment was tried this season. This substance proved quite injurious to germination, altho the excessive moisture in midsummer may have been responsible in part for the low yield. Beneficial results were noted from seed treatment with corrosive sublimate. The plots from seed infected with black scurf, treated with corrosive sublimate, produced from 88 to 93 per cent clean seed. These two lots were treated, one before cutting, the other after cutting. The former yielded

117.3 bushels per acre and the latter 74 bushels. Seed treated with formaldehyde produced from 75 to 81 per cent clean seed, while the "no-treatment" plots produced only 48 per cent clean stock.

Insecticide test.—Paris green and lead arsenate in both powder and paste forms were used in the tests this year. No new results were noted, as all poisons proved effective. Powdered lead arsenate is a satisfactory poison because of the ease and economy of application.

Methods of planting.—The outstanding fact noted in the size-of-seed test was the ability of the large seed pieces and the whole seed to withstand flood injury. The highest yields were produced by the whole-seed plots. The heaviest potatoes were produced on the single-eye plots where 1-ounce seed pieces produced tubers averaging 5.23 ounces.

In the amount-of-seed-per-acre test the difference in yield between 12, 13, and 16 bushels of seed per acre was slight, the respective yields being 128, 136, and 138 bushels per acre. The 14- and 16-bushel lots each averaged 122 bushels, net, per acre.

Fertilizer tests.—The yields in the 3-year rotation in the fertilizer series were below normal because of weather conditions. No appreciable results could be noted from the different fertilizer applications. In fact, the no-treatment plots averaged highest, with a yield of 118.3 bushels per acre. Acid phosphate alone gave the lowest yield, producing but 74 bushels per acre.

In the 4-year rotation of the fertilizer series the average was 158.8 bushels per acre. Acid phosphate produced when alone, 135.44 bushels, and when combined with manure, 122 bushels, per acre.

Soil fertility test.—Wet soil conditions of midsummer proved directly disastrous to the yield of many of the soil fertility plots.

Seed selection.—The increase plots of the hill and tuber-unit selections were practically wiped out by the flood. However, these selections in the comparative test plots in most cases produced enough seed to maintain the pure-line selections for another year. Bin-selected seed withstood the adverse conditions better than field-run and run-out seed.

Rotation tests.—Many of the plots in the rotation tests suffered from the flood. In most cases where the plots were flooded, it is impossible to determine the percentage of injury, for the tops apparently recovered and made a good late growth. It was too late for the tubers to develop and attain marketable size.

DAIRY AND ANIMAL HUSBANDRY SECTION

The work in this section was carried on much as in previous years, including school, station, and extension work. A noticeable improvement was effected in the quality of the livestock kept at the station. The cattle section comprises herds of Guernseys, Shorthorns, Holsteins,

and Herefords. A purebred herd of Duroc Jersey breeding swine consisting of 7 brood sows and 13 gilts was maintained. The station flock of sheep consists of 23 purebred Shropshire ewes, 1 flock ram, 27 grade ewes in addition to 15 purebred lambs and 20 grade lambs. The grade sheep will be disposed of, as the purebred flock is now large enough for the facilities at the station. The horses are used for judging purposes, draft and farm work. Four purebred Percheron mares, five high-grade mares and colts make up the group.

POULTRY SECTION

The last year in several respects was very trying for the stock. Winter set in earlier than usual and continued with little mild weather until late in March. The spring was also long and cold with less than the average sunshine. All this contributed toward lowering winter egg production and also seriously affected the fertility of eggs for early hatching. Numerous complaints regarding these conditions indicate that they were general throughout the Red River Valley.

Profiting by the experience of former years, following a severe winter, incubation was delayed fully three weeks. As a result the hatches were 8 per cent above the average of former years, and 83 per cent of all artificially hatched chicks and 97 per cent of all hen-hatched chicks were reared to the age of four weeks, or past the danger point.

The results of the fourth year's work comparing pullets and hens as profitable egg producers resulted in the pullets producing a profit of \$1.77 per bird and the hens \$1.61 per bird. These figures show an advance over the former average of \$1.69 for the pullets and a reduction of the former average of \$1.62 for the hens. This experiment will be completed next year.

Two new experiments were begun. One, a test of the value of turning eggs while holding for incubation, showed a slight difference in favor of turning. The other was a comparison of the cost of operating coal-heated brooders and oil-heated brooders. This year's figures show a decided economy in favor of the coal-heated brooder. The cost of brooding 100 chicks for six weeks with a coal brooder was 45.3 cents and for the kerosene brooder, \$2.40. The coal cost \$13.25 per ton and the kerosene 20.5 cents per gallon.

WEST CENTRAL EXPERIMENT STATION, MORRIS

P. E. MILLER, Superintendent

In 1915 the practice of publishing an annual report of the station work was begun. These reports are circulated among the farmers of the district and are becoming increasingly valuable each year. The results of the many experiments conducted in 1919 are published in full in the 1919 report of the station.

ORGANIZATION

There were no changes in the organization of the station work in 1919. The personnel of the staff also remained the same. Several minor changes were made in some projects, but all established projects were continued essentially the same as in 1918. The lack of available ground suitable for experimental work will limit any expansion during the coming year.

NEW PROJECTS

Several new rotation experiments were begun in 1919. In order to determine the best methods of alternating grain crops grown alone and in rotation, alternate and continuous cropping experiments were begun with wheat, oats, and barley and also 3-year and 5-year rotations including corn, oats, and clover in the former and corn, wheat, oats, clover, and clover and timothy in the latter. With the standard 4-year rotations in the other projects, the crop rotation experiments are now very complete and the station should be in a position to give authoritative information concerning the various methods of crop rotation and the problems of soil management.

VISITORS' DAY

July 19 was designated as Visitors' Day. The farmers of the district were invited to spend the day inspecting the various field experiments and to become better acquainted with the work of the station. Guides conducted the visitors through the experimental fields and explained the purpose and results of the various experiments. The many field tests were at the right stage of growth to show the effect of the different soil treatments; and the varieties of small grains were approaching maturity, making it possible to see the character of growth, strength of straw, disease resistance, and yield possibilities of each variety. The attendance was so large and so much interest was manifested that it was decided to make the midsummer visitors' day an annual event.

AGRONOMY AND SOILS

Fertilizer experiments.—Rotation experiments with phosphate fertilizers have now been in operation six years. The rotation used in this experiment is corn, wheat, oats, and clover. All fertilizers except rock phosphate are applied once in the rotation—after clover and preceding the corn crop. Rock phosphate was applied in 1914 at the rate of 1 ton per acre. Manure is applied at the rate of 8 tons per acre and acid phosphate at the rate of 480 pounds per acre. A five-year average for wheat grown in this rotation is 22.4 bushels per acre without any fertilizer, as compared with 26.8 bushels per acre when 480 pounds of

acid phosphate was applied once during the rotation. The clover seeding of 1918 failed and barley was seeded on this series in 1919. Coming last in the rotation it was the fourth crop to get the benefit of the various treatments. The amount of available nitrogen was sufficient to produce an excellent crop. The untreated plots gave an average of 43.9 bushels per acre as compared to 50.2 bushels for acid phosphate and 50.6 bushels where barnyard manure was used. It thus appears that limited applications of acid phosphate may be used profitably with barley. The stand of corn was very uneven on the corn series and the results are not so uniform as they have been in past seasons. However, manure alone, and the combination of acid phosphate with manure, gave better results than did acid phosphate alone. Climatic conditions in 1919 interfered seriously with the oat crop and the plots seeded to oats in this experiment show no material increase due to the fertilizer treatments. Serious lodging on the treated plots even caused lower yields than on the untreated plots. During a 4-year period the acid phosphate plots have given 4.1 bushels increase over those that were untreated. The following are the averages of all plots for the last four and five years:

SUMMARY OF YIELDS ON FERTILIZER PLOTS, 1919, 1918, 1917, 1916, AND 1915

Plots	Treatment	Corn	Wheat	Oats	Clover	Barley
		4-year av. 1919-17- 16-15	5-year av. 1919-18 17-16-15	4-year av. 1918-17 16-15	4-year av. 1918-17 16-15	1919
		Bushels	Bushels	Bushels	Tons	Bushels
1- 7-13	No fertilizer	38.3	22.4	58.1	2.04	43.9
2- 8-14	Rock phosphate.....	39.9	23.5	60.8	2.65	48.4
3- 9-15	Rock phosphate and manure	43.7	24.9	62.4	2.77	49.2
4-10-16	Manure	43.0	24.6	62.1	2.54	50.6
5-11-17	Acid phosphate and manure	43.7	26.5	61.1	2.74	43.3
6-12-18	Acid phosphate	41.5	26.8	62.2	2.57	50.2

Rates of application of acid phosphate.—Experiments were begun in 1918 to determine the most profitable rate of application of acid phosphate on wheat and clover, these two crops having previously given the most profitable returns from the use of acid phosphate. A 2-year rotation of wheat and clover is used and the rates of application of the fertilizer vary from 50 to 200 pounds per acre each year. So far no definite conclusions can be drawn, altho indications are that the lighter applications may prove most profitable.

Fertilizers with alfalfa.—These experiments were begun in 1915 and the results for 1916-17 and 1919 are given in the station report for 1919. The plots winter-killed in 1917-18 and were reseeded in 1918. Thus far the increases due to the use of fertilizers with the exception of acid

phosphate are too small to warrant their use with alfalfa. Over a 3-year period acid phosphate has shown an increase of slightly more than half a ton of hay per acre over the untreated plots.

Rates of manuring.—In 1916, in order to determine the most profitable rate of application of manure, an experiment was begun on a rotation of corn, wheat, barley, and clover. Manure is applied to the clover sod before plowing for corn at rates varying from 0 to 32 tons per acre. One rotation has been completed and data of value should be obtained from now on.

Alfalfa rotations.—In 1916 an 8-year rotation including four years of alfalfa and four of grain and corn was begun in order to determine the most profitable sequence in which to grow these crops and the value of alfalfa as a rotation crop. Four series are now in operation. The yields of grain in 1919 were among the highest produced at the station, as there was plenty of rain for both grain and corn during the growing season. By comparing the yields of corn grown after alfalfa with those following other crops during the same years, there is seen a material increase in the dry as well as in the normal years. Wheat and barley yields were reduced somewhat during the dry years and thus far it is evident that corn following alfalfa is preferable to small grains. The yields of corn in 1919 were the highest yet grown in this project.

Crop residues as fertilizers.—Experiments to determine the manurial value of wheat straw and stover were begun in 1916. A 2-year rotation of corn and wheat is followed. Corn stover is plowed under in the fall at the rate of 0, 1, and 2 tons per acre, and wheat straw at the same rate. Results for the four years indicate that one-ton applications are more beneficial than the heavier ones, also that corn is more benefited by the addition of residue than wheat. The 4-year results are given below.

WHEAT AND CORN YIELDS ON CROPS RESIDUE PLOTS, 1919, 1918, 1917, 1916
AVERAGE YIELD OF CORN

	1919	1918	1917	1916	4-year average
	Bu.	Bu.	Bu.	Bu.	Bu.
Straw, two tons	41.9	31.1	46.7	29.7	37.3
Straw, one ton	48.4	31.3	46.8	34.4	40.2
No treatment	38.9	25.7	38.2	33.2	34.0

AVERAGE YIELD OF WHEAT

	1919	1918	1917	1916	4-year average
Stover, two tons	11.3	30.1	25.0	7.9	18.6
Stover, one ton	12.1	33.3	25.2	8.4	19.7
No treatment	10.0	28.4	25.5	9.1	18.2

Clover utilization rotation.—A comparison of the various methods of utilizing red clover in a 4-year rotation of corn, wheat, barley, and clover with timothy was begun in 1916. Thus far the results do not indicate that it would pay to plow under the clover, as the increased yields do not compensate for the loss of the clover crop. There is an indication that higher yields of corn may be obtained after the crop of clover has been pastured.

New rotation experiments.—As the majority of farmers grow small grains year after year on the same ground, alternate cropping experiments with barley and wheat, barley and oats, and wheat and oats, as well as each of these crops grown continuously on the same land, were begun in 1919 in order to see the effect of these various methods of cropping on crop yields and soil fertility. A 3-year rotation of corn, oats, and clover and a 5-year rotation of corn, wheat, oats, clover hay, and clover and timothy hay were also begun. With the 4-year rotations of corn, wheat, oats and clover; and corn, wheat, barley, and clover, included in experiments already reported, the station now has a very comprehensive set of rotation experiments, designed for farms of various sizes, and for the different systems of farming.

Varietal tests of farm crops.—All the standard varieties of farm crops were included in the 1919 varietal tests. Five-year averages are now available for two varieties of wheat, four of oats, two of barley, and two of corn. Seven varieties of wheat were tested in 1919. The rust injured the wheat and decreased the yields. Mindum was the highest yielder of the durumms with 20.9 bushels per acre; and Marquis, of the red spring wheats, gave the highest yield, 17.9 bushels per acre. Thirteen varieties of oats were tested. Rust and lodging as well as extremely hot weather did considerable damage at the time the oats were heading. Kherson yielded 39.1 bushels and Iowa No. 103, 38.9 bushels, with Silvermine, O. A. C. No. 72, and Swedish Select following in order. Improved Ligowa, Minnesota No. 281, and Kherson have shown the best results over a 5-year period, the former yielding 54.7 and the latter 53.6 bushels per acre. All varieties were seeded April 29 at the rate of 80 pounds per acre. Seven varieties of barley were tested. Minsturdi gave the highest yield, while Svansota and Chevalier, both 2-rowed strains, showed very good results. Improved Manchuria, Minnesota No. 184, is the highest yielding 6-rowed barley and is used on all check plots and rotation work. Over a 5-year period Chevalier has given a somewhat higher yield than Wisconsin Pedigreed, an Oderbrucker selection and a six-rowed barley. Of the five varieties of winter wheat grown at the station in 1919, Turkey X Odessa, No. 1507, gave the highest yield, 11.4 bushels. All varieties were badly affected with rust and scab. Dry soil conditions in the fall caused an inferior fall growth and severe winter-killing resulted. Both spring and winter

rye gave good results. The increased yields from winter rye and the better distribution of labor make it a more practical crop than spring rye. Swedish, Minn. No. 2, has shown excellent results, is a very good yielder, and is extremely hardy, having a 3-year average of 26.6 bushels. Rosen, a Michigan selection, has not shown up so well as Swedish. Early September seeding proved best for winter rye.

Soybeans are gaining in favor and there are many calls for information concerning this crop. Seven varieties were tested in 1919. All matured well and gave good returns. Soysota was the highest yielder, with Chestnut and Elton coming in order. Fourteen varieties of field beans for table use were tested in 1919. This being the first year, no definite conclusions can be drawn. On a basis of this year's results, however, M. A. C. Robust showed superior yielding qualities with Great Northern second. Both are white beans.

A long growing season with plenty of rain during July, August, and September furnished ideal conditions for corn in 1919. There was no damage from early frost and all varieties matured well. Seven varieties were tested. Rustler White gave the highest yield with Minnesota No. 13 second. A 5-year average shows 42.4 bushels for Minnesota No. 13 and 27.6 bushels for Minnesota No. 23. Dakota White was the best of the flint varieties. Minnesota No. 13, Minnesota No. 23, and Northwestern Dent have all shown a tendency to mature very consistently.

In the alfalfa nursery, twenty-four varieties have been tested in the last five years. In 1917 and 1918 winter-killing was very severe with most varieties, Minnesota Grimm, Baltic, and Turkestan coming through with the best records. Grimm and Turkestan also showed highest yields for 1919. The results of these tests tend to show that permanent fields of alfalfa, even with the hardiest varieties, are not yet a reality. Winter-killing in 1918-19 and 1917-18 was the most severe during the 5-year test. The ground was very dry during the fall of both years, which seems to be a big factor in the winter-killing of both clover and alfalfa.

Corn selection work.—In addition to the regular variety tests of corn which are made each year, selection work has been carried on with Minnesota No. 13 for the last six years. The original corn of this variety was obtained in 1913. It has been carefully selected each year for yield, maturity, and type, and has been developed so that it will mature in about one hundred and ten days. It is now producing an average yield of 50 bushels per acre of air-dried corn. One hundred of the best ears were selected and planted in centgener rows in 1919, from which the earliest and heaviest yielders were selected to be used for planting in 1920. This is being distributed to corn growers throughout the district and very good results are being secured.

POTATO EXPERIMENTS

Variety tests.—Variety tests of potatoes have been carried on for two years. In both 1918 and 1919 there was a shortage of moisture throughout the growing season and the yields were not up to the average. Eight standard varieties were included in the variety trials. In 1919 Early Ohio was the best yielding early potato, and Rural New Yorker the best yielding late variety.

Spraying for early blight.—In 1919 spraying experiments, using bordeaux mixture on Early Ohio potatoes for early blight (*Alternaria solani*) were begun. The results are decidedly in favor of spraying. The total yield was increased 11.28 bushels per acre while the amount of unmarketable potatoes was decreased 5.41 bushels. On the whole, spraying resulted in a higher yield of larger and more mature potatoes.

Cultivation experiments.—Cultivation experiments with Early Ohio potatoes were begun in 1919. The plots were given level and ridged cultivation throughout the growing season. Hilling was detrimental, as it tended to dry out the soil and thus deprived the growing plant of the much needed moisture. It reduced the yield 5.11 bushels per acre.

HORTICULTURE

Bush and tree fruit investigations.—The variety tests of bush and tree fruits were increased in 1919 by the addition of several new varieties. The orchard planted in the spring of 1918 came through the winter in excellent condition and made very good growth in 1919. This orchard now contains 130 trees, including 30 different varieties of apples, plums, and cherries best adapted to Western Minnesota. Some new selections from the state fruit breeding farm are also included. Bush fruits came through the winter in excellent condition and made good growth in 1919. There was no winter-killing. The more tender species of raspberries and grapes are protected during the winter with a covering of earth, and the more hardy varieties are given a mulch of straw manure. Most of the currants, gooseberries, and raspberries set out in 1917 yielded considerable fruit in 1919.

Trees and ornamentals.—The purpose of the work with the various trees and ornamental shrubs is to determine their comparative value for farm planting under Western Minnesota conditions. All the standard varieties have been planted in the nursery and on the campus. These plantings are added to from year to year as new stock is obtained. All seedlings are set in the nursery and grown there until they are of proper size. They are then transplanted to their permanent location on the campus. The following varieties have proved very satisfactory for general planting, all being of the first degree of hardiness and able to withstand mechanical injury caused by winds, etc.: *Cotoneaster acutifolia*; *Cornus stolonifera* (Red-twigged dogwood); *Caragana arborescens*

(Siberian pea tree); *Lonicera tartaria* (Tartarian honeysuckle); *Lonicera morrowii* (Morrow honeysuckle); *Ribes aureum* (Missouri currant); *Ribes alpinum* (Alpine currant); *Rosa rugosa* (Japanese rose); *Syringa vulgaris* (Common lilac); *Sambucus canadensis* (Common elder); *Spirea sorbifolia* (Ash-leaved spirea); *Sambucus racemosus* (Redberried elder); *Viburnum opulus* (High-bush cranberry); *Viburnum lantana* (Wayfaring tree).

Variety testing of vegetables.—In 1919, 140 of the standard varieties of garden vegetables were grown successfully. Egg plant and lima beans did not mature before frost. Tomatoes did exceptionally well as the season was long with no early frost in the fall, allowing some of the early varieties to ripen all their fruit. Tomato plants are started in the cold frame and transplanted once before they are finally set out in the open ground. Watermelon, citron, muskmelon, and egg plants are started in pots in the cold frame.

ANIMAL HUSBANDRY

Experimental work in pork production was carried on in 1916 and 1917 and the results were published in the station reports of those years. The war made it advisable to discontinue this work, and abnormal conditions made it inopportune to do any work in 1919. There is an important field of work that should be done in both experimentation and demonstration, and it is hoped that in 1920 conditions will be favorable for a new beginning. The herds and flocks, which are maintained as demonstration breeding herds and for use in the classroom, all show material improvement.

NORTH CENTRAL EXPERIMENT STATION, GRAND RAPIDS

O. I. BERGH, Superintendent

Climatic conditions.—The season of 1919 opened earlier than usual, and field work was begun early in April. The first spring grain was planted April 17. Fine weather during the next three weeks made conditions favorable for field work, and corn and garden crops were planted early and germinated quickly. Because of warm wet weather in June spring grains grew rank and soft and rust developed early, practically destroying all that were seeded late.

Pastures were excellent, and the hay crop was one of the most bountiful ever harvested in this district. The rain did considerable damage to potatoes on poorly drained land, a large percentage of some fields being drowned out. The mean temperature of July and August was above normal, and precipitation was ample, 4.25 inches in July and 4.47 in August. The first killing frost occurred October 7, giving a growing season of 149 days.

The winter of 1919-20 extended from the last week of October to the latter part of March. The weather was uniformly cold, practically free from mild periods, but no extreme temperatures were reached, the minimum being 38 degrees below zero on January 18. There were no severe storms and from October 21 to April 1 the fields were well protected with snow. This was favorable for winter crops but unfavorable for logging, as the cedar and tamarack swamps remained unfrozen and in many cases the fields were frost free. Potatoes undug in the fall were in good condition when dug in April and May.

CROP YIELDS

On the whole the crop season of 1919 was satisfactory except for spring grains, which were partly or wholly destroyed by rust. The yields of the other farm crops were normal or above. The yield of hay was unusually large, as was that of corn, both grain and silage. Fruit was also abundant, especially wild blueberries and wild plums.

The yields per acre of grains on the main fields were as follows: Winter rye, Minn. No. 2, 23.5 to 24.7 bushels; winter wheat, Turkey Red, 17.15 to 19 bushels; Spring wheat, Prelude, 9.3 bushels; oats, Ligowa, 35.5 bushels; corn silage, 9.65 to 10.07 tons; sunflowers, green for silage, 6.5 to 12 tons; potatoes, 115.3 to 206.4 bushels; clover and timothy hay, 1.78 to 3.11 tons, first cutting. Most fields exceeded 2.5 tons per acre. Alfalfa yielded 3.45 tons per acre, first cutting, and 2.30, second cutting, a total of 5.75 tons.

In the wheat variety test the highest yields were made by the durums, owing to their greater resistance to rust. Acme gave the largest yield, 10.41 bushels per acre. The highest yielding of the hard wheats was Prelude, 2.68 bushels. The highest yielding variety of winter wheat was the hybrid Turkey x Odessa, Minn. No. 1507, a white bearded variety, with 22.7 bushels. A red awnless, Turkey x Odessa, Minn. No. 1493, yielded almost as well, 22 bushels. Emmer, which was included in the wheat variety test, out-yielded all wheat varieties with 21.48 bushels on the hulled basis.

The highest yield of oats, 45.67 bushels, was made by Iowa No. 103, an early variety. The highest yielding late oats was Victory, Minn. No. 514, 34.25 bushels. Among barley varieties, Minsturdi, Minn. No. 439, gave the highest yield, 40.27 bushels. Odessa and Manchuria, two other six-rowed varieties, yielded almost as well. Swedish Chevalier was the highest yielding two-rowed variety, producing 34.79 bushels. Of the winter ryes, Rosen gave the largest yield with 31.7 bushels per acre, followed closely by Swedish No. 2 and Wisconsin Pedigree. Potatoes yielded from 209 bushels for Early Ohio, to 414.2 for Green Mountain. The highest yielding early variety was Irish Cobbler, with 398 bushels.

Alfalfa investigation. Method of planting.—The seeding of alfalfa early in the spring with a nurse crop of spring grain, on land previously inoculated with soil from an old alfalfa field, fertilized with stable manure, and worked into a firm seedbed, gave a very good stand in 1918 which produced 5.75 tons of hay per acre in two cuttings in 1919. This confirms previous results obtained under the same methods of planting and soil management.

Time of planting winter grain.—Results from this experiment in 1919 substantiate those of former years and indicate that early planting is of more importance with winter wheat than with winter rye. Wheat should be planted in August in order to develop a strong root system in the fall. Rye planted in August out-yielded all later plantings, but large yields were obtained when sown as late as September 15.

Sunflowers and soybeans for silage.—Sunflowers and soybeans were planted for silage on a larger scale in 1919 than in any previous year. Both were very satisfactory. Soybean silage is especially relished, cows preferring it to first-class corn silage. They prefer corn silage to sunflower silage, but will eat thirty pounds of the latter daily and maintain a milk flow equal to that produced by the same amount of corn silage.

A mixed silage of corn, sunflowers, and soybeans can be recommended. Cows fed on this cleaned up forty pounds and more a day without showing a preference for any crop in the mixture. The seed was mixed in the following proportion: Corn, 3 parts; sunflowers, 1 part; soybeans, 1 part; and planted at the rate of 20 pounds per acre, drilled in rows 40 inches apart with a corn planter. This produced a larger tonnage than either corn or sunflowers planted alone.

Effect of different rates of applying manure for potatoes.—The effect in 1919 was similar to that of previous years. Potatoes receiving no manure yielded 139.8 bushels per acre; those receiving 5 tons, 223.3 bushels. Where 10 tons was applied the yield was 292.7 bushels, and where 20 tons was applied, the yield was 347.7 bushels. The average increase per ton of manure was 14.13 bushels. The increase was largest with an application of 5 tons of manure, being 16.7 bushels per ton. Where 10 tons of manure was used, the increase was 15.29 bushels per ton; and where 20 tons was used, the increase was 10.39 bushels per ton. The rate of application that can be recommended will depend on the amount of manure available. It is evident that 20 tons per acre can be applied with an increase in yield that will more than pay for the manure and the labor, and can be recommended if manure is abundant. Ten tons per acre seems to be more economical than 5 tons when the cost of labor is considered.

Oats and peas as a forage crop on peat land.—A small area of low-lime peat land used for growing oats and peas for hay has given large yields when treated with lime and stable manure. Ground limestone

was applied at the rate of from 2 to 3 tons per acre and manure at the rate of 10 tons, the regular amount used on mineral soils. Oats and peas averaged about 2.25 tons of hay per acre, and made excellent roughage for dairy cows.

Importance of lime on the station peat lands.—The grasses grown on peat land under various treatments indicate that liming is essential and where stable manure is not used, potash and phosphate, in the form of commercial fertilizer must be applied for clovers. For grasses grown without clover a nitrogen fertilizer is also necessary in order to obtain a satisfactory crop. The average yield of hay for three years, including 1919, from all grasses and all fertilizer treatments was 2.58 tons per acre where lime was added (4,000 pounds), while the three-year average yield where no lime was applied was 1.88 tons. Moreover, the smaller yield of hay from the unlimed plots contained 53 per cent of weeds by weight as against only 12 per cent in the hay receiving lime, or 2.27 tons of weed-free hay on limed peat and only 0.88 ton on unlimed.

Corn improvement.—Breeding work with a special strain of Minnesota No. 13, a yellow dent corn, was continued in 1919 and a large crop of seed of excellent quality was produced, much of which has been distributed to farmers in this district. Orders for seed corn have been received from the experiment stations at Bozeman, Montana, and Edmonton, Alberta.

LIVESTOCK

The work with livestock is being continued as in the past.

Poultry breeds.—The results with poultry so far show that the White Leghorn is the most profitable of the four breeds kept. The others are Rhode Island Red, Barred Plymouth Rock, and White Orpington. The Leghorns not only produced more and larger eggs than any of the others, but did it on less feed per hen.

Swine.—It has been necessary to reduce the swine herd on account of poor quarters, tho the swine department has been profitable and the demand for breeding stock has exceeded our supply. The number of brood sows was reduced last year from 20 to 7, with the intention, however, of increasing the herd again as soon as adequate quarters are provided.

Sheep.—A flock of 18 sheep was purchased in November, 1919, including 6 registered Shropshire ewes. The flock is headed by a registered Shropshire ram.

Management of the dairy herd.—The project of breeding up a herd of grade Guernseys is being continued. The herd is now headed by Duenota's 3rd Son, a bull of excellent type and backed by high production. Duenota 2nd, a full sister of his dam, has this year completed

a record of 12,781.2 pounds of milk containing 708.06 pounds of butterfat. He is also of large size, weighing over 1,800 pounds in breeding condition. The junior herd sire is Maids May King a son of Beda's May King out of Julians Island Maid with a record of 11,723.5 pounds of milk and 438.39 pounds butterfat as a two-year-old. This bull was purchased as a yearling in 1919. The first registered female owned by this station is First Maid of Woodend, purchased at a public sale in November, 1919. The production record of our herd was again broken last year, Brindle 2 making a record of 10,381 pounds of milk containing 543.5 pounds of butterfat. This record was made under ordinary farm conditions. She freshened again before the record was completed thus placing her in the double-letter class.

PERMANENT IMPROVEMENTS

Only minor improvements were made at the station last year, among which was a concrete root cellar which was necessary in connection with the potato investigation work carried on in coöperation with the United States Bureau of Plant Industry. The poultryman's cottage was moved to a more convenient location, and a full concrete basement was constructed under it. About ten acres of land recently cleared was broken and put into crops.

The new state highway from Grand Rapids to the towns on the Mesaba Iron Range has been surveyed and legalized. This new road will cross the station lands just south and east of the buildings and when completed will afford convenient transportation for the people at the station and visitors, as the passenger motor busses of the Mesaba Transportation Company will run on schedule, hourly, throughout the year.

NORTHEAST DEMONSTRATION FARM AND EXPERIMENT STATION, DULUTH

M. J. THOMPSON, Superintendent

The year 1919 was devoted primarily to reconstruction and reorganization following the destructive forest fire of October 12, 1918. Conditions necessitated three lines of effort: (1) Rebuilding of barns, dwellings, fences, and permanent equipment in general; (2) re-establishment of meadows and pastures and provision for immediate forage needs; (3) salvaging burned timber and converting the stump land into a productive area. Seasonal and labor conditions were favorable. All buildings but one were rebuilt and in use by April 1. Meadows and pastures were re-seeded and the forage, owing to good weather, was the best in several years. About twenty acres of timber was cut off and the land seeded to grass.

WEATHER CONDITIONS

Following a winter of almost unexampled mildness, spring opened very early. Aside from a dry spell in July the growing season of 1919 has probably never been excelled in the agricultural history of North-eastern Minnesota. Sunshine and rainfall were ample and well distributed. The last severe frost of the spring was on May 5 and the first corresponding minimum temperature (29 degrees) was recorded September 27, and it was barely sufficient to kill potato vines. The frost-free period of 145 days made possible the ripening of corn, tomatoes, cucumbers, and other tender crops. The summery weather abruptly changed about October 20. New snow records were established for both October and November, and December was abnormally cold.

FIELD CROPS

Variety tests of grains.—These are now on a definite basis. A five-year rotation has been established to provide two years of grain, two of grass, and one of cultivated crops, in coöperation with the Division of Agronomy and Farm Management. Six varieties of spring wheat were under test, eight of oats, five of barley, and four of beans. The durum wheats were outstanding, Mindum producing an average of 27 bushels in a poor year. Victory and Iowa No. 103 oats led other varieties with yields respectively of 53 and 55 bushels. Oat yields were low owing to the ravages of the army worm, which in some cases stripped entire fields. Barley made excellent yields, with field averages above 50 bushels per acre. Svansota, a two-rowed barley, out-yielded other varieties with 53.76 bushels per acre. Spring rye produced 32 bushels per acre. Brown Swedish bean and Snowflake, a white navy, each yielded 23 bushels per acre.

Forage crops.—The first harvests were removed from the grass plots in 1919. Redtop, *bromus inermis*, bluegrass, timothy, and orchard grass produced in the order named. Clovers and alfalfa ranked in this order: Alsike, mammoth, Grimm alfalfa, sweet clover, medium red clover. In all cases except alfalfa, one crop only is recorded. The average of all grasses was 3,350 pounds per acre; of clovers, including alfalfa, 3,670 pounds. Weak germination and thin stands on a high location in the dry season of 1918 reduced yields. Four millets were under test for hay with an average yield of 6,134 pounds per acre.

Silage crops.—Corn is uncertain at the head of the lakes, owing to cool nights. Five types of substitute silage crops were grown: Millet (four varieties), sorghum, clover, sunflowers, and peas and oats. The last made a low average of 9,528 pounds per acre, or less than five tons, owing to late seeding following another crop. Millets, sorghum, and sunflowers averaged respectively, 6.7, 15.8, and 18.3 tons per acre.

The last two were relished by the cattle better than the first. Second-crop clover made a good quality of silage, well relished by the stock.

Potato investigations.—The potato work proper was developed along four lines:

(1) *Place effect on Early Ohio stock.*—Three year's work showed that the factor of location was more important than any other in determining yield.

(2) *Variety testing.*—The eight standard varieties were under test in triplicate plots for the second year. Bliss Triumph, Early Ohio, Irish Cobbler, Green Mountain, Rural New Yorker, Russet, King, and Burbank yielded respectively 181, 216, 227, 283, 204, 262, 254, and 300 bushels per acre.

(3) *Seed treatment.*—Three lots of Green Mountain seed stock were treated respectively with corrosive sublimate, formalin, and copper sulfate, and a fourth lot was untreated. These lots were planted in triplicate plots. The object was to determine which was the most effective treatment for disease. All potatoes harvested were equally clean, however, but the first two lots each produced about twenty-five bushels less than the untreated lot, and the third seventy-five bushels less.

(4) A project on cultivation methods was begun. One series of plots was ridged and another series was cultivated level. There was a difference of about five per cent in favor of ridging.

Pastures.—Pasture studies have been continued. Young stock averaged a daily gain of 1.33 pounds in 1919. Horses maintained weight on night pasture while on steady work during the day. Brood sows kept in good flesh and produced a second litter of pigs in the early fall with half the normal grain ration supplemented by pasture.

CROP ROTATION STUDIES

The cost of plowing, the shortage of labor, and the certainty of a good hay crop, together with its importance in the existing dairy type of farming, is causing many farmers at the head of the lakes to change from a 3-year to a 4- or 5-year rotation with most of the land in hay. In 1919 a series of 36 plots was laid out in order to study this problem of farm management. A 3-, 4-, and 5-year rotation system is provided in triplicate. The rotation consists of barley, clover, sunflowers; barley, clover and timothy two years, sunflowers; barley, clover and timothy three years, sunflowers. In 1920 all crops are represented and the work is well under way.

Rye is an important crop in this region, but it must be adapted to a workable cropping plan. In 1919 a rotation of rye, clover, early potatoes was begun. The plan is to get the potatoes off in late August in time for an early seeding of rye, not later than September 1.

SOIL FERTILITY EXPERIMENTS

The soil fertility experiments are carried on in coöperation with the Division of Soils, University Farm.

(1) *Phosphate-manure plots.*—This project has passed through its fourth year with as yet no marked effect from the phosphates unless combined with manure. The check plots maintain yields remarkably well. They have produced a 4-year average yield of 172 bushels of marketable potatoes per acre, and 12 tons of rutabagas, together with a 3-year average of 51 bushels of oats. The limed half of the hay plots produced 13 per cent more hay than the unlimed in a 2-year average.

(2) *Clover utilization.*—In these plots clover is plowed under, pastured, and harvested in three groups of two plots each. In 1919 there was no material difference in yield of potatoes and rutabagas from the several plots, but with oats there was a good margin in favor of the pastured plots.

(3) *Cropping without either clover or manure.*—This project is four years old. Barley is almost an absolute failure, but potatoes, rutabagas, and oats produce about three-fifths as much as when, in each 3-year rotation, clover is grown and manure applied.

(4) *Rate of manuring.*—Five tons per acre has produced the largest return per ton of manure applied, in potatoes, and ten tons per acre in hay and oats. Measured by the crops grown, the effect of manure has been surprisingly small on the clay loam soil of this farm.

ANIMAL HUSBANDRY

The Guernsey dairy herd now has eight purebred females. Twenty-two head constitute the productive herd, with an average of eighteen in milk at all times. Improvement is being accomplished by culling, feeding, and the use of a wellbred sire. Purebred male calves find a ready market. Milking is done by a machine, now in operation for two years, at a great saving in labor.

Yorkshire hogs are still bred and raised. Two litters per year are produced and sold among the farmers of the district at weaning time. A beginning has been made on a herd of Duroc Jerseys.

In October, 1919, this station purchased its first flock of sheep. Twelve grade Hampshires were bought for use in land-clearing operations in 1920. The poultryman has charge also of the sheep.

Efforts are being concentrated on White Leghorns, altho a small flock of Rhode Island Reds is also maintained. A flock of about three hundred breeding and laying birds is wintered, and about 1,000 are hatched annually. The work is limited to demonstrations of flock improvement, culling, use of males from high producing stock, distribution of breeding stock and eggs, proper feeding and care, and the utilization of local feeds.

HORTICULTURE

Gardening.—In this district gardening on a commercial scale is an important industry. The limiting factor is manure with which to maintain good production. A project begun in 1919 is under way in which green manures are substituted for and compared with the barnyard product. There are two series of three blocks each, in which early vegetables, late vegetables, and peas are respectively grown in duplicate blocks. Two applications are made in three years on one series, and to correspond with this one crop of rye and one crop of peas are plowed under for green manure, on the other.

Orchard.—Nearly one sixth of the trees were either killed or very severely injured by the forest fire of October, 1918. No replanting was done in 1919, as the extent of the damage could not be known until late in the season. In like manner the forest plantation southwest of the buildings was entirely killed out. Replantings were made in both cases and a standard windbreak was planted in the spring of 1920.

SOUTHEAST DEMONSTRATION FARM AND EXPERIMENT
STATION, WASECA

R. E. HODGSON, Superintendent

THE DEMONSTRATION FARM

Numerous improvements have been made at the demonstration farm during the year, both on the land and on the buildings. Some fields were plowed two and three times in an attempt to control quack grass. This intensive and repeated cultivation must be continued for some time before the fields will be free from sod. A considerable number of large and small stones have been hauled from the fields, making possible more thoro and convenient tillage.

A small barn, 24 by 50 feet, to house the young stock, was the chief improvement made in the farmstead. One half of the farrowing pens in the hog house were paved with hollow tile in order to compare this floor with cement, which covered the other half. The pens paved with hollow tile were dryer, warmer, and generally more satisfactory.

Some new machinery was purchased during the year, the chief item being a No. 17 ensilage cutter. This machine is also capable of pulverizing alfalfa and corn fodder, and these chopped feeds will be tried out in comparison with the uncut products.

The farm crops of 1919 were not as good as they should have been. It was a very wet year, and clearly demonstrated that the tile system now in the ground will have to be inspected to locate parts not in working order; and in addition, a much larger number of laterals put in. Table I shows the crops raised, the acreage of each, and the yield.

TABLE I

ACREAGE AND YIELDS, 1919

	Acres.	Yield per acre
Fodder corn.....	5	3 tons
Ear corn.....	35	40 bu.
Silage corn.....	25	7 tons
Corn for hog pasture.....	5	.....
Oats and peas for hay.....	5	1½ tons
Oats and peas for grain.....	5	20 bu.
Oats	25	25 bu.
Timothy hay	25	1 ton
Clover (On Ex. unit).....	20	2 tons
Rape hog pasture.....	2½	.....
Sugar beets.....	2½	8 tons
Soy beans.....	2½	12 bu.
Sweet clover hog pasture.....	2½	.....
Total	165	

The dairy herd is the chief livestock enterprise. The Department of Agriculture has adopted the policy of concentrating the dairy Short-horns owned by the University, at Waseca, and five purebred heifers were sent down from University Farm, St. Paul. The rest of the herd, with the exception of the herd sire, are grades. The total milk production for the calendar year 1919 was 105,588.9 pounds, an average of 6,938.4 pounds for the mature cows. During the year, 29 calves were born. One pair of twins died soon after birth, and one calf had acute indigestion. These were the only losses of cattle during the year.

Combined with dairy production, the herd maintains a beef conformation which prompts local butchers to pay St. Paul prices for surplus stock. For example, a heifer 27 months old from one of the high-producing cows weighed 850 pounds and brought \$85 at the local market with no special feeding.

Cash receipts from dairy products during the year amounted to \$2,440.49. Sales of cattle brought \$1,364.52 and inventory increases were \$1,289, a total of \$5,093.91. Milk valued at \$1,116.43 was fed on the farm, making a total production for the herd of \$6,210.34.

The Poland China hogs were the most profitable enterprise. While all of them are purebred, registration papers are kept up on only a few and no effort is made to sell breeding stock. The total sales of hogs for the year amounted to \$4,437.11.

The sheep this year were kept on new pastures and were not bothered with stomach worms. A fine flock of lambs was produced, the first sixteen being the product of nine ewes. The wool crop was light, owing to the poor condition of the sheep last summer and fall. Only 20 ewes are now kept, largely as a means of combating weeds. In this

way they pay for themselves. Total sales of wool and mutton for the year amounted to \$449.77.

THE EXPERIMENT STATION

A more definite organization has been built up at the experiment station during the year. A good team of horses (one a purebred Percheron) has been maintained to do the necessary teamwork, and in addition, they are expected to raise the colts necessary to keep up the supply of horses on the farm. Grant A. McColley, a plotman, has been employed to do the team work on the experimental plots and to take care of a large part of the planting and harvesting. In the winter he is employed in caring for the stock at the experiment station unit, which will include a carload of fattening cattle, the flock of sheep, and five colts. He will also separate the oats and peas, clean the seed grain, and test the seed corn.

The usual variety tests of cereals were conducted this year, and ground was prepared for expanding the work during the coming season. Additional land was cleared, making 32 acres available for experimental work. The results of the crop season of 1919 have been reported in the Annual Report of the Southeast Substation for 1919.

The greatest need of the station at Waseca, is adequate buildings. Besides Institute Hall and the feeding shed, there are no modern buildings on the place. Building and improving has been deferred to await developments in regard to the proposed School of Agriculture. If the work now under way is to be maintained, however, it will be absolutely necessary to have a new seed house and corn drying room in the very near future. The work on corn experiments and the proposed quantity production of pedigreed seed are especially hampered by lack of storing and housing facilities. A new silo to replace the one now in use is also a necessity.

FRUIT BREEDING FARM, ZUMBRA HEIGHTS

CHARLES HARALSON, Superintendent

The fiscal year ending June 30, 1920, brought about some changes at the fruit breeding farm. A new section to the greenhouse was completed, making available more space for the crossing of tubbed trees and plants in late winter and early spring. A large storage cellar, 26 by 80 feet, was begun in the fall, but was not advanced far enough to be of service during the winter. At the close of the fiscal year it was very nearly completed, making available a larger space suitable for winter storage of tubbed trees. A packing and storage shed was erected over the storage cellar.

New land for which \$14,000 had been appropriated was purchased during the year and consists of thirty-two acres, eight of which lie north

of the original farm and square up the irregular north boundary of the place, making it include a considerable part of the shore of Tamarack Lake. Twenty-four acres lie to the west of the north "forty" of the fruit breeding farm, occupying a place just across the road from the farm buildings. This is an excellent piece of land and will furnish a much needed expansion in orchard planting.

New Fruits.—During the year it was decided that some of the productions of the fruit farm had been sufficiently well tested to be worthy of receiving permanent names. Accordingly a committee of the State Horticultural Society, including the superintendent of the fruit breeding farm and the chief of the Division of Horticulture, selected the following names and filed them in the office of the American Pomological Society:

Apples: Minnehaha, formerly Minnesota No. 300.

Plums: Elliott, formerly Minnesota No. 8; Red Wing, formerly Minnesota No. 12; Tonka, formerly Minnesota No. 21; Underwood, formerly Minnesota No. 91; Monitor, formerly Minnesota No. 70.

Strawberries: Minnesota, formerly Minnesota No. 3; Minnehaha, formerly Minnesota No. 935; Duluth (Everbearing), formerly Minnesota No. 1017.

Raspberries: Latham, formerly Minnesota No. 4.

Cherry-plum hybrid, Zumbra, no numbered production.

Several of these fruits are now being propagated by nurserymen. The Latham raspberry and the Minnehaha strawberry are proving especially popular.

A new feature of the work during the last season was the storage test of apple varieties. Owing to inadequate facilities at the fruit breeding farm, this test was carried on in the storage cellar at University Farm. Several promising seedlings were in excellent condition until April 1.

REPORT OF COMMITTEE EXAMINING MINNESOTA STATE FRUIT BREEDING FARM 1920

To the Regents of the University of Minnesota and the Minnesota State Horticultural Society.

Gentlemen:

In accordance with the custom of previous years, the committee appointed to inspect the fruit breeding farm and report to the Horticultural Society made its visit August 17, in company with about thirty members of the Minneapolis Civic and Commerce Association. It was personally a pleasure to the chairman of the committee that President Smith appointed as the other member of the committee Commissioner Holmberg, who introduced the bill creating the fruit breeding farm in the Legislature.

We were shown over the place by Superintendent Haralson and had an opportunity to inspect carefully the various phases of the work being carried on. As has been uniformly reported in previous years, we found the farm in good condition and the plants and various fruits given good care. To one unacquainted with the breeding of new plants the great variety of seedlings on hand was bewildering. We found extensive plantings of seedlings of apples, plums, raspberries, gooseberries, grapes, and strawberries. Several other fruits, as well as nuts and roses are being worked to a lesser extent. We shall review briefly the outstanding features of the work with each.

Apples.—We were surprised to find a large number of new seedling apples of special promise. It seems that from this list something of promise as a late keeper will surely be found. One of the new apples has been named "Minnehaha." This appears to be justified, judging from the promise shown by the original tree, both in fruit and tree characters. Nos. 11, 237, 308, 311, 365, 424, 447 and a large number of others of apparently equal merit, will warrant careful study by the fruit growers in the future. Storage tests have shown that a number of these new seedlings will keep well toward spring and some of them, especially Nos. 447 and 424, until spring or early summer. About 450 seedling apples have been given numbers. Exhibits of these at the state fair and at the winter meeting of the Horticultural Society will give an idea of the high standard set in the preliminary selections. It will require considerable time and much careful work finally to weed out the few best types. In spite of the fact that there are about 450 apple varieties already marked for study, we found the apple crosses being pushed to the limit of the greenhouse space. In the seedbed 3,000 new seedlings are growing from the previous year's crosses. This will give some idea of the extent of the work being carried on with the apple.

Plums.—We were shown that plums could be grown in Minnesota. A trip through the trial plots, where Elliott, Red Wing, Tonka, Zumbra, Nos. 30, 50, 91, and 111, and others of nearly equal promise were fruiting heavily, showed the possibilities of plums in Minnesota. As in the case of apples, we were surprised at the great variety of new seedlings from which selections are being made. In plot No. 1 alone it appeared evident to even a casual observer that here were some new seedlings which would eventually be given a permanent place on the plum variety list in Minnesota as well as in other states, on account of their promise as to both fruiting qualities and hardiness. After going over these new seedlings, especially Zumbra, we wondered if we had not reached the time here in Minnesota when we could transfer our plum industry from the old list of native varieties to a new list made up almost entirely of seedlings from the fruit breeding farm, with the addition of a few others originated elsewhere. As in the case of apples, we found trees

in the greenhouse loaded to capacity with new crosses, and a large number of seedlings in the seedbed growing from crosses made the previous season.

Strawberries.—We were shown over nearly eight acres of seedling strawberries which represented increase rows of the best seedlings derived from the work of the ten years preceding. This year final selections were being made and we had an opportunity to see first hand how carefully this work is being done, because some of these varieties had been grown continuously for several years before being finally recommended for distribution or discarded. In the case of the everbearers the new plantation was especially interesting and showed some new seedlings that would certainly rival the old standards like Progressive and Superb. Nos. 41 and 42 appeared to be most promising. Of the spring-bearing varieties we wish to emphasize that in seedlings like Nos. 935, 775, 999, 489, 97, and 593, we have what appear to be varieties of unusual merit. For a commercial berry, No. 935 is not injured by rains when ripe and will stand shipping unusually well. No. 775 appears to be unsurpassed as a home berry. These represent the final selections of what is considered by those in charge, the first attempt at strawberry breeding. As with other fruits, strawberry breeding will continue and will be for the most part based upon the new seedlings originated at the fruit-breeding farm.

Raspberries.—It is difficult to overestimate the place that the Latham (formerly Minnesota No. 4) has among the raspberry growers in Minnesota. While some of the standard varieties challenge Latham in certain localities, it is probable that none of them will prove more generally adaptable in Minnesota. Some of the newer seedlings are being given a place equal to Latham and in some respects even superior to it. Of course the hardiness and general fruitfulness of these new types are yet to be demonstrated, but it will be a difficult task finally to weed out the few dozen new seedling raspberries from among the 250 which have been marked. Crosses are being made between Latham and selected types of the wild raspberry from Manitoba to see if it is possible to obtain a hardier variety. Here we found a large number of seedlings growing in flats and a large number of crosses which had been made in the greenhouse. It is doubtful if any of the new fruits are more outstanding in general merit than the Latham red raspberry. We were interested to know that an attempt was being made to get a hardier blackberry by crossing standard varieties like Snyder with wild berries from the northern part of the state.

Gooseberries.—Among the new seedling gooseberries were some that may largely supersede the older varieties. While many of us have been accustomed to seeing gooseberries lose their leaves in early mid-summer, some of these new types maintain a healthy green foliage

until the fall frost. In productiveness and size of fruit some of these newer seedlings, especially some of the crosses with the English gooseberry, seem to have special promise. Those who are interested in this fruit in a commercial way will do well to examine these new seedlings and try them out for their own locality.

Grapes.—The Beta seedlings have been under test for several years. They have been exhibited several times and there has been ample opportunity to test their hardiness. These varieties are productive and none of them have shown any winter injury, even during a severe winter like 1917-18. Some of the new crosses between Beta and the standard varieties were promising. There were seedlings of promise in the three prevailing colors, namely, blue, green, and red. We found a considerable number of crosses on vines in the greenhouse, and seedlings growing in the seedbed.

There are also other fruits that we might discuss. The committee attempted to observe in detail what had actually been accomplished by the breeding work, as well as a general inspection of the state of cultivation and the general care of the place. We were delighted to find so many seedlings of such promise and before we left we began to appreciate how difficult the problem actually is of weeding out these new fruits and finally determining their value. This leads your committee to suggest that greater attention should be given in the future to testing the new productions at the horticultural trial stations, as well as at the state institutions. It may be that with the mass of new material coming from the fruit-breeding farm it will be impossible for individuals at the horticultural trial stations to handle this new material on the scale that should be required of them. If the tests are not made in a way that will show quickly the relative merits of the new seedlings for the various sections of the state, the growers will not know what to call for and nurserymen will not know what to propagate. Even after rigid selection has been made at the fruit-breeding farm there still remains a large number of seedlings from which the best must be selected. This is a task for the whole society and it can not be accomplished at a single place like the fruit-breeding farm. It should be possible for every person receiving new fruits as premiums through the Horticultural Society to send in a report as to the promise of each in his locality.

The financial support of the station will have to be increased. With the increased cost of supplies and labor, with the new land becoming available next year, your committee recommends that this organization give its support to increasing the budget for the fruit breeding farm. We recommend, after going over the work with those in authority there, a minimum of \$16,000 annually.

We were pleased to find that an arrangement had been practically completed for about 28 acres of additional land and that a new storage

and fruit building was under construction and would be ready for use this fall. It will be necessary in the near future to provide another greenhouse for the crossing work, because the work at the fruit breeding farm is a continuous process and while some seedlings are being discarded others are being created. We have attempted to enumerate the extent to which the variety list is gradually being changed over to seedlings from the fruit breeding farm. This fact alone shows that the machinery operating there is effective and that it is accomplishing the work for which it was created.

Respectfully submitted,
B. B. SHEFFIELD
N. J. HOLMBERG
Committee.