KANSAS AGRICULTURAL EXPERIMENT STATION

KANSAS STATE AGRICULTURAL COLLEGE

DIRECTORS' REPORT, 1913

MANHATTAN, KAN.

6–1508

K A N S A S

AGRICULTURAL EXPERIMENT STATION.

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KANSAS AGRICULTURAL EXPERIMENT STATION.

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1 In cooperation with the United State Department of Agriculture.

KANSAS AGRICULTURAL EXPERIMENT STATION.

OFFICE OF THE DIRECTOR,
JUNE 30, 1914.

To His Excellency, G. H. Hodges, Governor of Kansas:

I have the honor to present herewith the report of the Kansas Agricultural Experiment Station for the fiscal year ended June 30, 1914. It includes a brief statement of the principal changes which have occurred since the issuance of the last report.

W. M. JARDINE, *Director.*

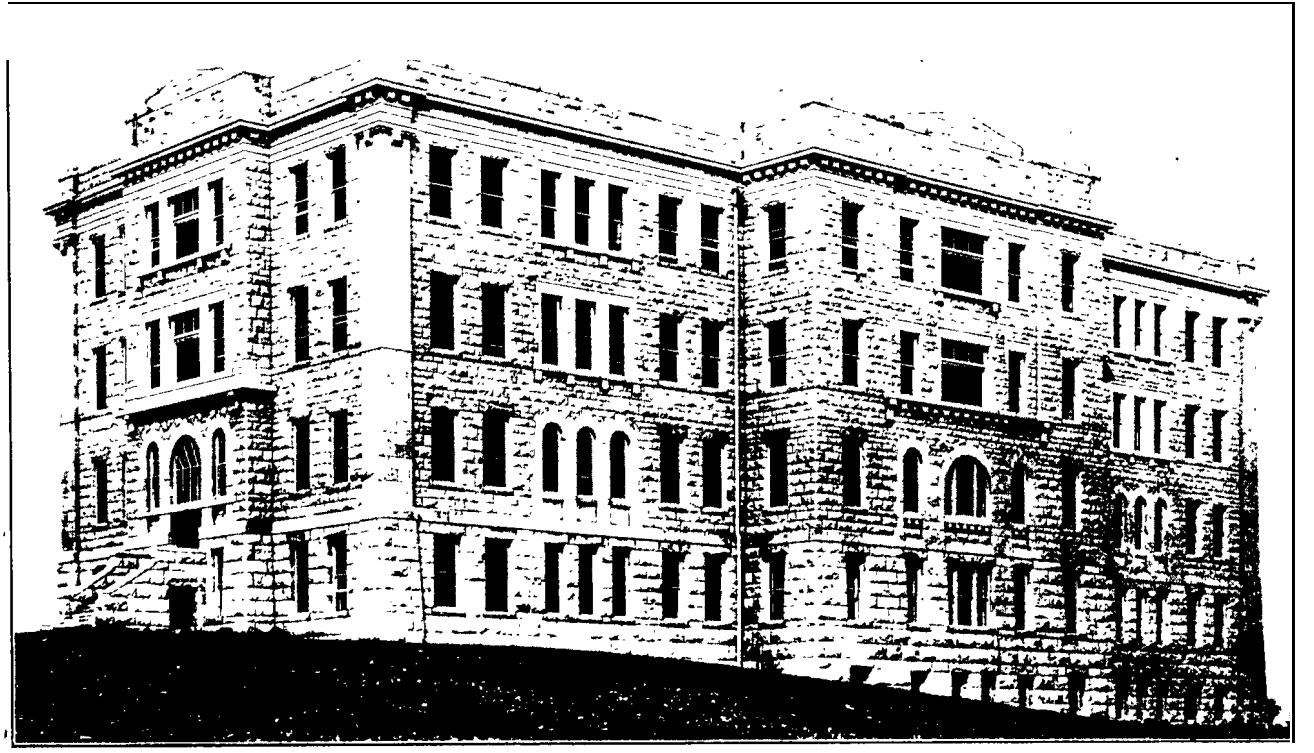

FIG. 1.

THE DIRECTOR'S REPORT.

SINCE the publication of the last report, in 1908, many changes have occurred at this station. These changes point toward progress in practically every instance. The 320-acre farm which was purchased in 1909 provides a place where field experiments on problems such as long crop rotations, soil fertility and soil culture may be continued without interruption. The fields adjoining the campus, formerly used for this work, are now available for the live stock used for experimental and demonstration purposes. The department of dairy husbandry here maintains 113 head of the four principal breeds of dairy cattle, while the animal husbandry department maintains 44 horses, 225 beef cattle, 375 hogs, and 100 sheep. These animals are excellent representatives of the types best adapted to this section of the country. A splendid stone barn has been completed, which provides ample space conveniently to house the horses and show cattle of the animal husbandry department. Twelve silos have also been erected for the experimental work of the two departments.

A separate department for poultry has been created and an eight-acre tract of land conveniently located adjacent to the campus has been set aside for its use. An average of 500 mature standardbred fowls are now accessible at all times for experimental and student work.

The first wing of the proposed $400,000 agricultural hall has been completed. This building (fig. 1) furnishes room for the administrative offices of the experiment station, as well as office, laboratory and classrooms for the departments of agronomy, animal husbandry, milling industry, and poultry husbandry. A complete modern flour mill is a part of the equipment of this building. A six-section experimental greenhouse has been added to the equipment of the station and a nutrition barn and laboratories for the work in animal nutrition have been provided. A view of the interior of the new dairy barn (fig. 2) is shown on page 6.

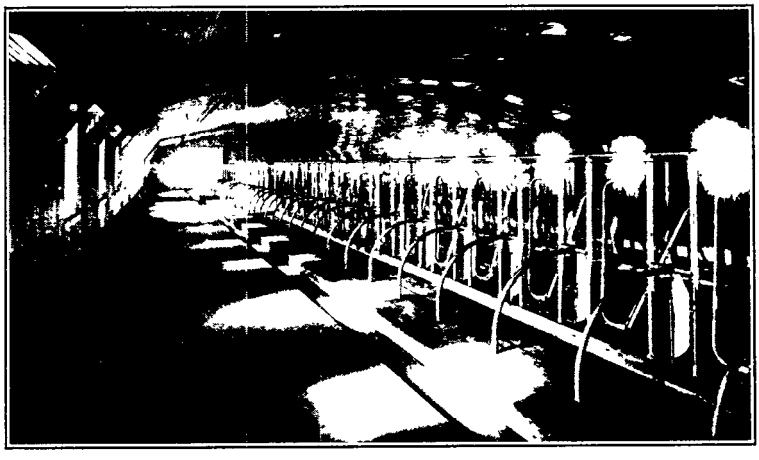

FIG. 2.

Additional substations and demonstration farms have been provided. Figure 3 shows the location and work of the demonstration farms, while figure 7 shows the location of the substations, the date of their establishment and the lines of work being conducted in coöperation with the federal government. Detailed soil surveys of seven counties have been made by this station, in coöperation with the Department of Agriculture. Figure 4 shows the districts in Kansas where soil surveys have been completed.

PERSONNEL.

The following are the most significant changes in the station staff since the last report was issued. Director C. W. Burkett was succeeded by E. H. Webster in 1908, and in 1913 Director Webster was succeeded by W. M. Jardine, agronomist at this

EXPLANATION OF FIG. 3.

1. Variety test of sorghums.
2. Variety test, of corn.
3. Variety test of wheat.
4. Fertilizer tests. Wheat, oats, and alfalfa.
5. Crop improvement projects. Improving corn or sorghums by field selection or by the "ear or head-row method."
6. Testing out miscellaneous crops such as Sudan grass, Sweet clover, Lespedeza (Japan clover), cowpeas, Spanish peanuts, and Mexican beans.
7. Outlying experimental farms.

NOTE.--In some of the counties having county agents there are so many experiments under may that it, is impossible to include them all on the map.

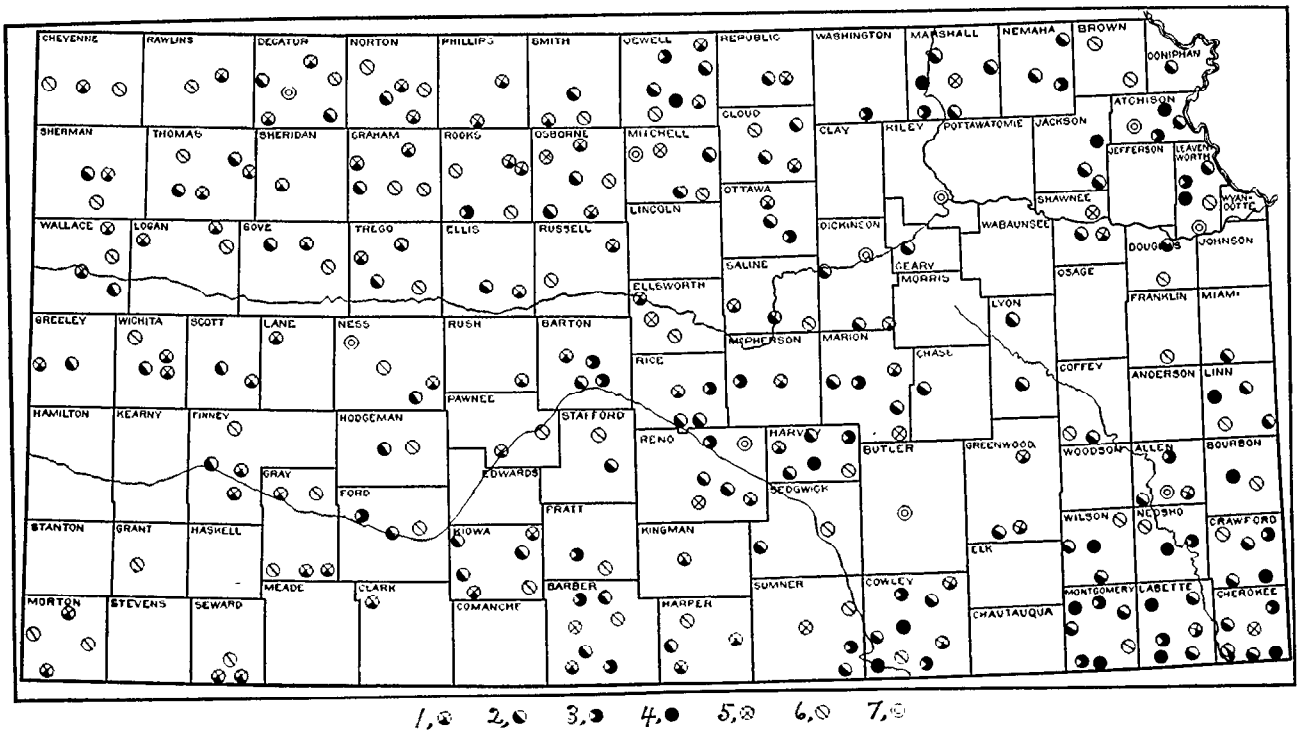

FIG. 3. Map showing the location of cooperative experiments conducted in 1914.

station. Director Jardine had become agronomist July 1,1910, succeeding A. M. Ten Eyck. T. J. Headlee, entomologist and zoologist, left this station in 1912 to take up similar work at the New Jersey station. The department was then divided, entomology being placed in charge of George A. Dean and zoölogy in charge of R. K. Nabours.

J. C. Kendall, dairy husbandman, was succeeded by O. E. Reed in the fall of 1910. The poultry work was taken out of the dairy department January 1, 1912, and a separate department established in charge of Wm. A. Lippincott. L. A. Fitz was put in charge of the newly established department of milling industry March 1, 1910. R. J. Kinzer, who resigned as animal husbandman January 1, 1911, was succeeded July 1, 1912, by W. A. Cochel. L. E. Call succeeded W. M. Jardine as agronomist in the fall of 1913. The office of state forester was established by an act of the legislature in 1909 and C. A. Scott put in charge the following year. D. M. Wilson was succeeded as state dairy commissioner by D. S. Burch September 1, 1911, who was in turn succeeded by George S. Hine July 1,1912.

The station staff has been increased until there are now seventy-three members, exclusive of the coöperators of the Department of Agriculture, engaged in experimental work with cereals, dry-land agriculture, and irrigation farming at the western substations in this state.

PUBLICATIONS ISSUED.

Forty-five bulletins and forty circulars giving valuable information, based principally upon investigations carried on at the station and its substations, have been printed and distributed. Seventeen of these bulletins and eight circulars were published and distributed during the fiscal year ended June 30, 1914. The station mailing lists now contain approximately 20,000 names. In 1913 the old lists were discontinued and a notice sent to all whose names appeared, stating that it would be necessary to file a written application for bulletins in order to appear on the new mailing list. It is a fact significant of the keen appreciation of the work of this station that before the close of the year 20,000 such applications were received.

A tabulated list of the publications issued between July 1, 1913, and June 30,1914, is herewith appended:

BULLETINS AND CIRCULARS ISSUED FROM JULY 1, 1913, TO JUNE 30, 1914.

Bulletin No.	*Title.*	*Edition.*	*Pages.*	*Total pages.*
185	Preparing Land for Wheat	20,000	15	300,000
186	Feeding Work Horses	30,000	51	1,530,000
187	Analysis of Registered Fertilizers	10,000	10	100,000
188	The Hessian Fly	10,000	54	540,000
189	Mill and Stored-Grain Insects	10,000	96	960,000
190	The Influence of Certain Substances on the Baking Qualities of Flour	8,000	48	384,000
191	The Chinch Bug	10,000	66	660,000
192	Hog Feeding	30,000	72	2,160,000
193	Corn	15,000	41	615,000
194	Potato Culture	30,000	18	540,000
195	The Analysis and Registration of Commercial Feedstuffs	4,500	27	121,500
196	The Control of Apple Blotch	12,000	53	636,000
197	Alfalfa in Kansas	30,000	35	1,050,000
198	Kafir in Field and Feed Lot	20,000	23	460,000
199	Chemical Analyses of Some Kansas Soils	15,000	82	1,230,000
200	Soil Survey of Shawnee County, Kansas	2,000	32	64,000
201	Some Factors Influencing the Bacterial Content and Keeping Quality of Eggs	15,000	38	570,000
	Totals	271,500	761	11,920,500
Circulars.				
31	Seed Corn for Kansas	5,000	3	15,000
32	Burning the Chinch Bug in Winter Quarters	25,000	7	175,000
33	The Chinese Arbor Vitæ	20,000	7	140,000
34	Sweet Clover	20,000	6	120,000
35	Report of the Dickinson County Cow-testing Association	20,000	8	160,000
36	Preparation of Exhibits for Fairs and Contests	10,000	7	70,000
37	The Hessian Fly Situation in Kansas	15,000	4	60,000
38	The Kansas Feeding-stuffs Law, Revision of 1913	5,000	7	35,000
39	Cream Grading for Kansas	100,000	4	400,000
40	Suggestions that Will Assist in the Prevention and Control of Hog Cholera	30,000	4	120,000
	Totals	250,000	57	1,295,000

SUMMARIES OF BULLETINS.

185. *Preparing Land for Wheat.* (L. E. Call.) This bulletin discusses the preparation of the seedbed for wheat, including the cost of preparation, the yield, and the value of grain and straw. Eleven different methods were used for wheat grown continuously, and five methods for wheat grown in rotation. The value of early plowing and rotation systems is emphasized.

186. *Feeding Work- Horses.* (C. W. McCampbell.) An extensive horse-feeding experiment was conducted at the Fort Riley Military Reservation, in which timothy, alfalfa, prairie, and small-grain hays were compared, and grain mixtures were fed in comparison with oats. The feed and care of the stallion, brood mare and foal, and growing horses are treated.

187. *Analyses of Registered Fertilizers.* (J. T. Willard, C. O. Swanson, and R. C. Wiley.) A report of analyses of inspection samples of fertilizers is presented. A statement of the receipts and expenditures under the provisions of the fertilizer law from October 1, 1907, to December 31, 1912, is included. The quality of fertilizers offered is generally up to the guaranty.

188. *The Hessian Fly.* (T. J. Headlee and J. B. Parker.) This treatise deals with the history and introduction of the insect, its complete life history and habits in this state, and all of the principal measures of control.

189. *Mill and Stored-Grain Insects.* (G. A. Dean.) Two-thirds of this bulletin is devoted to measures of control and the remainder to the life history and habits of the common stored-grain and mill insects. Preventive methods are emphasized, the heat method for flour mills being given in detail. Hydrocyanic gas fumigation and carbon bisulphide fumigation for granaries are also described.

190. *The Influence of Certain Substances upon the Baking Qualities of Flow.* (J. T. Willard and C. O. Swanson.) The baking qualities of flour were found to bear an intimate relation to chemical substances naturally present, or that may be produced from normal constituents of flour or through imperfect milling. The most active substances seem to be derivatives of proteins which may be produced by germination, or by hydrolysis accompanying the breadmaking process.

191. *The Chinch Bug.* (T. J. Headlee and J. W. McColloch.) Outbreaks of the chinch bug in Kansas since 1870 are reviewed; its life history and habits with many new facts regarding hibernation and migration are presented; the chinch bug fungous disease is discussed; and various measures of control are given in detail.

192. *Hog Feeding.* (G. C. Wheeler and T. R. H. Wright.) Results of hog-feeding experiments conducted from 1904 to 1912 are included. Kansas-grown grains were fed in these experiments to determine their value and means of increasing their efficiency for fattening hogs by supplementing with feeds having a high percentage of protein. The value of pasture crops for growing pigs was also determined.

193. *Corn.* (A. M. Ten Eyck.) Results of variety tests of corn from 1903 to 1909 are given. The value of home-grown seed is emphasized. This bulletin also contains a brief history and the principal characteristics of the varieties in the state.

194. *Potato Culture.* (Albert Dickens.) A brief report is presented of fertilizer and culture experiments conducted at the experiment station and in coöperation with commercial growers. This bulletin also contains general methods for seed selection, cutting, treatment and planting, and discusses enemies and their control.

195. *The Analyses and Registration of Commercial Feedstuffs.* (L. A. Fitz.) A partial list of registered firms, together with the names and guarantees of their feeds, is given in this publication.

196. *The Control of Apple Blotch.* (D. E. Lewis.) A study of the apple-blotch fungus is presented, with reviews of the investigations carried on for three years, together with a general summary and recommendations for the control of the disease.

197. *Alfalfa in Kansas.* (W. M. Jardine and L. E. Call.) The importance of a good seedbed, clean, viable seed, and the proper time of seeding, together with the value of inoculation, lime and manure, are emphasized. The time of cutting for seed and hay and for storing is

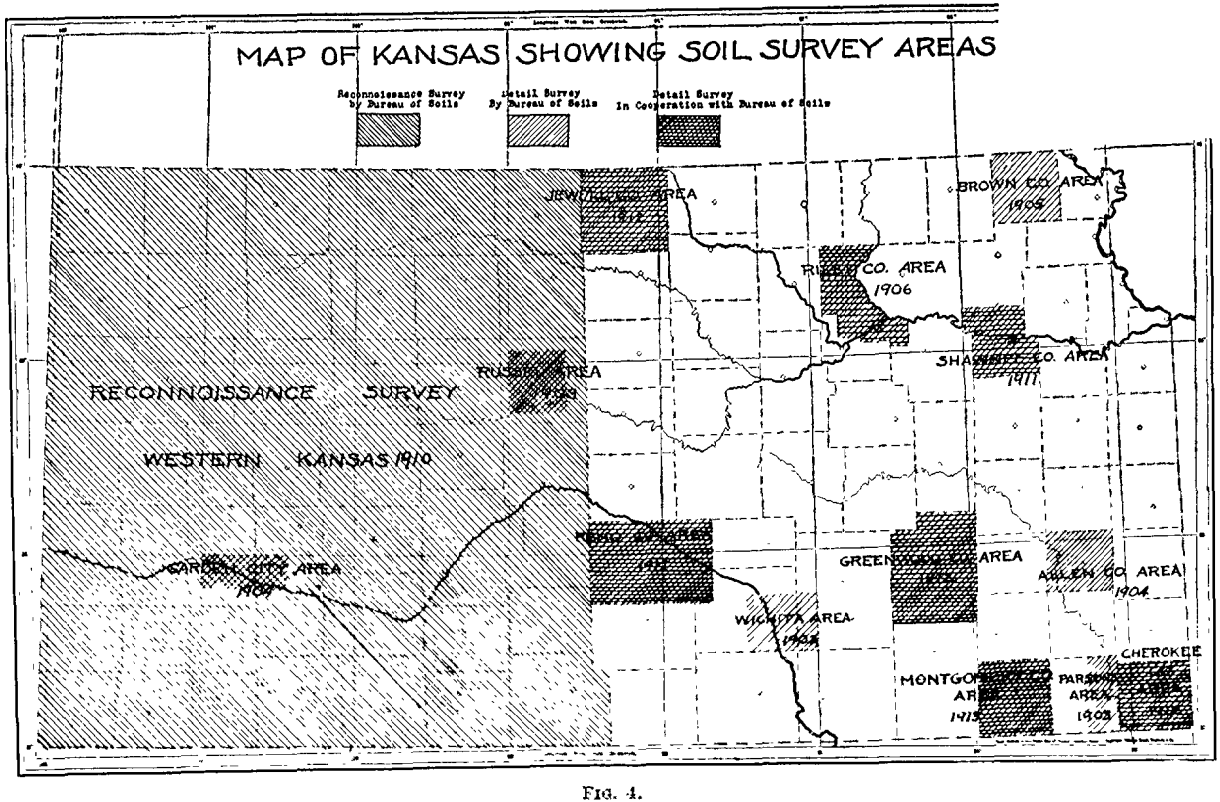

FIG. 4.

discussed. A brief description of insect damage is given and also methods of destroying the insects.

198. *Kafir in Field and Feed Lot.* (G. K. Helder.) Varieties of kafir for each section of Kansas, the method of preparing the seedbed and planting, systems of cultivation and harvesting; diseases and their treatment, and the improvement of varieties are discussed. The value of kafir as silage, pasture, stover and fodder for beef cows, beef steers and hogs is demonstrated.

199. *Chemical Analyses of Some Kansas Soils.* (C. O. Swanson.) A description of the soil types of all or part of Labette, Allen, Sedgwick, Butler, Harper, Brown, Doniphan, Riley, Russell, Finney and Gray counties is included, with chemical analyses of samples from all of these counties excepting Labette.

200. *Soil Survey of Shawnee County, Kansas.* (R. I. Throckmorton, W. C. Byers, C. O. Swanson, C. E. Millar, L. E. Call.) A brief description is given of each of the seventeen soil types found in the county. A chemical analysis of each type indicates the relative abundance of plant food. The latter part of the bulletin contains a discussion, "Maintaining Soil Fertility," which deals with the value of rotations, alfalfa, green manuring crops, barnyard manure, and commercial fertilizers. A soil survey map is included.

201. *Some Factors Influencing the Bacterial Content and Keeping Quality of Eggs.* (L. E. Bushnell and Otto Maurer.) Results of methods of reducing enormous losses due to the spoilage of eggs are reported. Several factors are no doubt responsible for this deterioration, this work covering the changes that are of microbial origin. Data showed almost all of the eggs containing bacteria to be infected in the yolk; very few showed the presence of bacteria in the white. The conclusion derived was that the quantitative method used for determining the infection in eggs does not furnish a very reliable index to the influence of the various factors upon their keeping quality.

SUMMARIES OF CIRCULARS.

31. *Seed Corn for Kansas.* (L. E. Call.) This paper instructs farmers where and how to obtain the best seed corn, and warns them against the use of mixed corn shipped in for seeding purposes. The importance of the germination test is emphasized.

32. *Burn the Chinch Bug in Winter Quarters.* (G. A. Dean and J. W. McColloch.) Attention is called to the damage the chinch bug does during the summer; directions are given for finding it in its winter quarters; the importance of burning is emphasized; and methods of organizing cooperative burning are suggested.

33. The Chinese Arbor Vitæ. (C. A. Scott.) The adaptation of the Chinese arbor vitæ to Kansas conditions, methods of propagation and its desirability for ornamental and wood-lot planting are discussed.

34. *Sweet Clover.* (C. C. Cunningham.) Directions are given for preparing the seedbed for sweet clover and for seeding and handling for hay or seed. The value of sweet clover as a pasture crop and soil improver is also discussed.

35. *Report of the Dickinson County Cow-Testing Association.* (O. E. Reed.) Results of the first year's work of the association are given in this circular. A brief outline of the plan of organization is provided, together with the records of the best and poorest cows.

36. *Preparation of Exhibits for Fairs and Contests.* (G. E. Thompson.) Brief directions for the collecting of exhibit material are herein contained, together with method of making bundles of small grain, the types of ears of corn to show, and the method of selecting heads of kafir, milo and feterita.

37. *The Hessian, Fly Situation in Kansas.* (G. A. Dean and J. W. McColloch.) Wheat growers are warned of the serious outbreak of Hessian fly confronting them, are given effective and practical measures of control, and are urged to coöperate.

38. *The Kansas Feeding-stuffs Law Revision of 1913.* (L. A. Fitz.) The feeding-stuffs law is summarized in this publication, and certain rules and regulations in regard to the registration and sale of commercial feeds are included.

39. *Cream Grading for Kansas.* (G. S. Hine.) This circular was published simultaneously with the actual adoption of cream grading by the creameries of Kansas, and a copy was given to each producer of cream. It explains methods of grading as well as the purposes and advantages of the system.

40. *Suggestions that Will Assist in the Prevention and Control of Hog Cholera.* (F. S. Schoenleber.) A statement of measures that must be adopted to prevent the spread of hog cholera, with instructions as to cleaning the premises during and following an outbreak, is here presented.

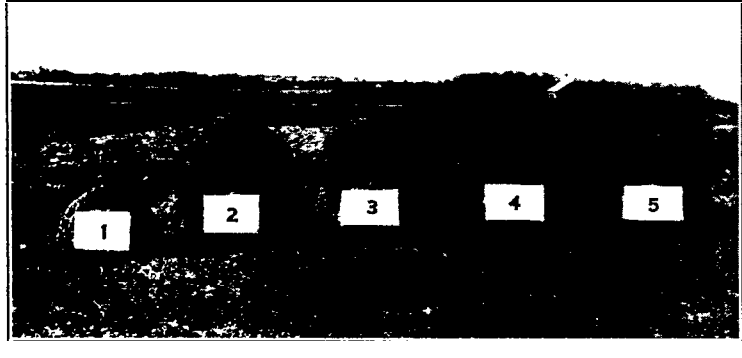

FIG. 5. Yield from one-tenth of an acre of alfalfa, first cutting, fifth year in alfalfa.

1. Unfertilized; yield per acre, 640 pounds.
2. Five tons of manure annually; yield per acre, 2460 pounds.
3. Two and one-half tons of manure annually; yield per acre, 1800 pounds.
4. Two and one-half tons of manure and 380 pounds of raw rock phosphate annually; yield per acre, 2140 pounds.
5. Unfertilized; yield per acre, 860 pounds.

In addition to these official publications, the staff members have prepared numerous papers along the various lines of applied science, which make up the varied research activities of

this station. These have been presented at meetings of the associations representing these respective lines of work, or have appeared in the leading scientific periodicals. A partial list of these papers is given herewith:

PAPERS APPEARING IN SCIENTIFIC JOURNALS.

"Methods of Cell-Division in the Sex Cells of *Tænia tæniaformis.*" Mary T. Harman, *Journal of Morphology,* vol. 24, pp. 205-243.

"The Innervation of the Integument of Chiroptera." James E. Ackert, *Journal of Morphology,* vol. 25, pp. 301-343.

"The Use of Milk Cultures of *B. bulgaricus* and the Prevention of Bacillary White Diarrhea of Young Chicks." L. D. Bushnell and Otto Maurer, *American Veterinary Review, vol.* 44, pp. 194-207.

"Further Data on Heat as a Means of Controlling Mill Insects." George A. Dean, *The Journal of Economic Entomology,* vol. 6, pp. 40-52.

"Grasshopper Control Work in Western Kansas." George A. Dean, *The Journal of Economic Entomology,* vol. 7, pp. 67-75.

"Report of the Official Entomologist for 1912." George A. Dean, *Transactions of the Kansas State Horticultural Society,* vol. 32, pp. 78-88.

"Report of the Official Entomologist for 1913." George A. Dean, *Transactions of the Kansas State Horticultural Society,* vol. 32, pp. 180-184.

"Report of the State Entomologist." George A. Dean, *Third Annual Report of the Kansas State Entomological Commission,* pp. 14-20.

"A Parasite of the Chinch Bug Egg." J. W. McColloch and H. Yuasa, *The Journal of Economic Entomology,* vol. 7, pp. 219-227.

"Studies of the Enchytræidæ of North America." Paul S. Welch, *Bulletin of the Illinois State Laboratory of Natural History,* vol. 10, pp. 123-212.

"The Early Stages of the Life History of *Polystoechotes punctatus* (Fabr.)." P. S. Welch, *Bulletin of the Brooklyn Entomological Society,* vol. 9, pp. l-6.

"Observations on the Life History and Habits of *Hydromyza confluens* Loew. (Diptera)." P. S. Welch, *Annals of the Entomological Society of America,*" vol. 7, pp. 135-147.

"Entomological Abstracts." P. *S.* Welch, *Transactions of the American Microscopical Society,* vol. 32, pp. 300-302, vol. 33, pp. 59-60, 142-145.

"Studies of Inheritance and Evolution in Orthoptera I." R. K. Nabours, *Journal of Genetics,* vol. 3, pp. 141-170.

"Some Factors Producing Evagination of a Cysticercus." J. W. Scott, *Biological Bulletin,* vol. 25, pp. 304-312.

"New Means of Transmitting the Fowl Nematode, *Heterakis perspicillum.*" J. W. Scott, *Science,* n. s., vol. 38, pp. 672-673.

"Preliminary Study on the Conditions which Affect the Amylolytic Enzymes of Wheat Flour." C. O. Swanson and J. W. Calvin, *Journal American Chemical Society,* vol. 35, pp. 1635-1643.

"Acidity in Silage; Method of Determination." C. O. Swanson, J. W. Calvin, and E. H. Hungerford, *Journal American Chemical Society,* vol. 35, p. 476.

"The Influence of Germination on the Milling Qualities of Wheat." C. O. Swanson.

I-A. "Influence on the Qualities of Flour from Germinated Wheat." *Operative Miller,* vol. 18, pp. 98-100.

I-B. "Methods; Influence on the Bread-making Qualities of Flour from Germinated Wheat." *Operative Miller,* vol. 18, pp. 165-167.

II. "Effect of Extract of Shorts of Germinated Wheat." *Operative Miller,* vol. 18, pp. 225-227.

III. "Baking Tests of Flour from Germinated Wheat." *Operative Miller,* vol. 18, pp. 293, 294.

IV. "The Effect of Mixing Flours from Germinated Wheat with Flour from Sound Wheat. *Operative Miller,* vol. 18, pp. 365-368.

"Chemical Composition of Wheat Compared with Resultant Flours." C. O. Swanson, *American Miller,* vol. 41, pp. 218-222.

"Wheat Conditioning." C. O. Swanson, *American Miller,* vol. 41, pp. 467-469.

Experimental Work.

It is impossible to report the various lines of research work in detail. A brief summary indicating the progress which has been made in the more important lines of investigation is presented herewith, grouped according to the funds from which they receive their financial support.

HATCH FUND.

Soil Fertility. Investigations in soil fertility were started in 1909 and have since been continued along the lines originally planned. The principal object of these investigations is to determine the effect upon the yield and quality of the principal farm crops, of various fertilizers, such as barnyard manure, green manure and commercial fertilizers, when used alone or in combination with each other. Three cropping systems are followed: In the first each crop is grown continuously upon the same land; in the second, corn, cowpeas and wheat are rotated, each crop being grown one year out of the three; and, in the third, a sixteen-year rotation of alfalfa, corn and wheat is followed. Alfalfa is grown for four years, followed by corn for two years and wheat for one year. Then the corn and wheat are continued in this way completing a period of twelve years.

Commercial fertilizers have in most instances not increased the yield of the cereal crops sufficiently to pay for their cost. Fertilizers supplying phosphorus have proved profitable upon alfalfa. Barnyard manure has increased the yield of all crops.

The most marked increases have been with alfalfa (fig. 5), although two and one-half tons of barnyard manure applied annually upon wheat has returned $1.75 a ton in the increase of crop secured.

Seedbed Preparation for Wheat. The results of this work will be found in the latter part of this report.

Crop Experiments. Studies have been continued with the small-grain cereal crops and with corn and forage crops in an endeavor to produce better and higher-yielding varieties for growing under the soil and climatic conditions existing in Kansas. A few pure strains of wheat are proving of superior value and have been distributed this year for trial with farmers in different parts of the state, to determine their yielding value compared with standard varieties. One of these strains has given an average yield at Manhattan during the past three years of 4.8 bushels more than the standard Turkey wheat. Milling and baking tests show it to be of equal quality.

Forty-one varieties of field peas were grown this past year and valuable data were obtained on drouth resistance. One hundred single plant selections of cowpeas and soybeans were grown. Canadian field peas and oats combined for hay yielded as high as 2.9 tons to the acre. In the silage test comparing sweet sorghums, kafir and corn, Kansas Orange sorghum produced 8.5 tons, kafir 5.5 tons and Boone County White corn 5.7 tons to the acre, respectively.

The season of 1913 was so unfavorable for the production of corn that practically no results were obtained. None of the selections or varieties produced grain. The plants were harvested for a total yield of silage. The earliest varieties and thickest rates of planting produced the heaviest yields.

Soil Bacteriology Investigations. Soil bacteriology investigations were started in 1913, to determine the bacteriological differences between plots cultivated and fertilized in different ways. So far, constant differences between the plots have not been apparent as a result of any of the methods proposed, except where there were great differences in the method of treatment. Other methods of testing are being devised with the hope that they will prove more delicate.

Bacterial Study of Poultry Diseases. A bacterial study of poultry diseases was started in 1913, in an endeavor to determine practical methods of treatment and control of the

common diseases of poultry, with special reference to the cause of roup. The causative factor of roup is apparently not in the blood, as injections into healthy birds do not give rise to the disease. Intramuscular injections of caseous exudate gave typical symptoms in a few cases. Intravenous, intraperitoneal and subcutaneous injections did not give typical cases.

Dairy Bacteriology Investigations. The relations between the microbial flora of first and second grade cream as graded on the basis of five-tenths percent acidity could not be determined from a bacteriological standpoint, but when graded according to flavor and odor there was a predominance of the favorable types (acid) over the undesirable types (colon and digestion).

Phgsiological Investigation with Drouth-resistant Plants. Investigations in drouth resistance of plants have been in progress for a number of years. In 1910 a supposedly drouth-resistant variety of corn from China was obtained through the Department of Agriculture. Numerous crosses were made between this and six different varieties of dent corn from western Kansas. In 1911 a Mexican corn called Esperanza was secured through the Department of Agriculture. The best hybrids from the Chinese-Kansas corn were crossed with the Mexican corn. The F_2 segregates from this cross were grown in 1913. The season of 1913 was one of excessive drouth and high temperature, but all the special strains showed unusual resistance to drouth and gave great promise for the future in this respect. Some of these substrains produced white dent ears, while most of them were extraordinary in their development of leafage, forming very broad, heavy leaves, which remained green to the base of the plant, and which give great promise as producers of ensilage and forage corn. These hybrids, being in the F_2 generation, may possibly be fixed in some of their characters. Coöperative experiments in growing these hybrids are being carried on at various points in the western half of the state during the season of 1914. It is hoped to determine the exact water requirements of these hybrids as compared with standard varieties of corn grown in the middle West.

The first systematic work on the physiological study of corn, milo and kafir plants in regard to their water supply was

begun in the spring of 1914. Plants were started in large cans in order to make a thorough study of their transpiration. The root systems of all named plants at any early stage have been studied and material for anatomical study has been collected. The water content of the leaves has been studied at different periods. Weather instruments have been installed so that complete records of the conditions under which the plants grow may be available.

Rust Resistance in Wheat. Work on this project was started in 1912, in coöperation with the Department of Agriculture, to investigate the disease resistance of the cereals. It has been continued until this year, when six families of hybrids between rust resistant, spring and purebred local winter wheats have been produced. Data on head smut of sorghum and corn smut have also been gathered in a study of the exact mode of infection of corn smut, to determine whether infection is strictly local or whether it may be systemic.

Hessian Fly Investigations. The study of the life economy of the Hessian fly and methods of control has been conducted since 1907. Experiments conducted this year show all wheat planted on or after the established fly-free date to be free from injury. Two complete generations of the fly have been reared in the field insectary during the spring, and six generations in the glass insectary during the winter. Extreme drouth and hot weather did not prevent a serious outbreak of the fly. Four species of parasites have been obtained, some of which are probably new.

Corn-Ear Worm Investigations, Investigations have been continued to complete the life history of this insect and to determine the life history and importance of the parasites which live upon it. Owing to the extreme drouth and great heat of last summer, very little was accomplished in the experiment on the time of planting. The night habits of the moth were studied and some data obtained. Many data were also obtained on the effect of climatic conditions on the various stages of the corn-ear worm.

Chinch-bug Investigations. This work was a continuation of the studies of previous years. The life history of the chinch bug under known conditions was under consideration. In reaching the adult stage the chinch bug was found to pass through five instead of four molts. Data on the effect of cli-

matic influences on the life economy of the chinch bug were obtained. Wind was found to be a very important factor in the distribution of the bugs from their winter quarters. Good results were obtained through fall burning as a means of controlling chinch bugs.

Fruit Insect Investigations. Studies in the seasonal life history of the plum curculio under Kansas conditions were continued from the previous year, and promising methods of control were devised and tested. Lime-sulphur and Bordeaux sprays were tested as repellants for the curculio. Variety tests were conducted to ascertain if some varieties of apples wholly resist aphis. Considerable work was done on the life history and control of termites or white ants.

Grasshopper Investigations. Work has been continued in investigating the parasites and other insect enemies of the grasshopper and to determine their role in natural control. The life history of the Kansas grasshopper has been investigated and a microscopic study of the eggs of the Kansas Acrididæ has been made in order to discover specific characters if possible. An inquiry has been made into the habits and life history of several important species of grasshoppers. The efficiency of poisoned bran mash flavored with orange juice was thoroughly demonstrated by hundreds of farmers during the past summer. About one thousand tons of the mash were distributed.

Investigation of Farm Wood Lots in Southeastern Kansas. A survey has been made of two river valleys in the southeastern part of the state and a large amount of data regarding the present stand has been secured.

ADAMS FUND.

Nutrition Investigations. In July, 1910, experiments were planned for the purpose of studying the uses of food in the animal body. Two lines of investigation were begun:

1. To determine the deficiencies of corn as a ration for young pigs.

2. To determine the effects of the plane of nutrition on the body development of cattle.

Four feeding trials including ninety pigs have been completed. Results show that young pigs fed cornmeal without other feed are much below normal development at the close

of six months; that young pigs fed cornmeal supplemented with various ash ingredients are much below normal development at the close of the six months; that young pigs fed cornmeal supplemented with proteins low in ash develop normally during six months' feeding. These results indicate that a protein deficiency, either quantitative or qualitative, or both, is the chief limiting factor. The influence of the ash in combination with the protein has not been determined.

Two feeding trials including twelve steers are in progress. Results show that scanty feeding does not materially hinder growth in height, but greatly retards development of middle and width of body; that one year of maintenance feeding, if followed by liberal feeding, does not materially stunt the animal, but does not allow maximum development of width of body; that two years of maintenance feeding followed by liberal feeding results in permanent stunting, which is indicated by lack of normal height, contracted middles and narrow bodies.

Bacteriology of Freshly Laid Eggs. These investigations were started in 1910. Part of the results were published in Bulletin 180, in 1911. The final report has been completed and is now ready for publication.

Wheat-breeding Investigations. From 1906 to 1910 over two thousand new strains of wheat were produced by selection, a number of which are now being increased. In 1909 experiments in producing wheats with some of the hardy characteristics of the speltz, emmers and durum wheats were begun. Of the forty-five families of hybrids between various purebred wheats and different sorts of speltz, emmers and durums started in 1909, twenty-three families have survived to the present year. The F_3, segregated types show: (1) wheat parental characters in pure form; (2) speltz characters in pure form; (3) emmer characters in pure form; (4) wheat characters combined with certain spelt characters or certain emmer characters.

Alfalfa-breeding Experiment. This study has been in progress for seven years. Thirty-five pure lines of alfalfa are being propagated. These show great differences in seed and forage production per hundred plants. The plan of this experiment has been revised this spring and contemplates a thorough study from the genetic standpoint of the drouth-resistant species and varieties of *Medicago* (alfalfa), and the determination of the manner and extent of the inheritance of such characters in

crosses with *Medicago sativa* varieties of superior forage value but inferior in resistance to drouth.

Mill and Stored-grain Insect Investigation. In the spring of 1910 a committee representing the Southwestern Millers' League and the Kansas millers visited the experiment station. They requested that the station so clean up insect infestation in the export mills that marine insurance of flour exported by way of the Gulf of Mexico might be renewed, it having been withdrawn on account of too great losses due to insect depredations. This work was undertaken and the results secured were so satisfactory that not only was the insurance readily extended, but a method of ridding mills of injurious insects (now known as the heating method) was devised and perfected, which because of its efficiency, simplicity and inexpensiveness has been adopted by the leading millers in the majority of the milling states and in many mills in Canada.

Climate and Injurious Insect Investigations. An endeavor is being made to change the germinal constitutions of one or more pedigreed species of *Paratettix* (grasshopper) and to observe the effect in the inheritance behavior. No effective work has been done on account of incomplete apparatus. An air-conditioning machine is now being installed, and this will make definite results possible.

Parasitology Investigations. In 1912 work on the life history of two chick tapeworms was started, but thus far the results have been negative. While carrying on this experiment a new means of transmitting a fowl nematode was discovered. An endeavor is now being made *to* determine whether the transmission of this fowl nematode *(Heterakis perspicillum)* by a dung earthworm *(Helodrilus parvus)* is a case of true parasitism, or simply an association. Other experiments on cestodes showed a way in which it may be determined why many tapeworms must have specific hosts.

Breeding Experiments. Studies in the fundamental laws of inheritance in several species of the order Orthoptera, which were started several years ago, are still in progress. A new unit character has been discovered which may be permanently bred into any individual of the group.

Corn Mold Investigations. The following facts have been established: (1) "Staggers" in horses is caused by moldy corn, the gross lesions consisting in congestion and softening of the

brain; (2) affected brains will not transmit the disease; (3) cocci isolated from infected brains are secondary invaders.

Complete studies of the molds and bacteria of moldy corn have been made. The following are still in progress: (1) Minute histology of softened areas; (2) fundamental chemical study of moldy corn, and the effect of isolated fractions of these substances upon guinea pigs.

STATE FUND.

Silage Investigations. Two studies in silage were begun in 1912. One was to determine the comparative value of silage made from corn, sweet sorghum and kafir in wintering high grade Hereford calves, and one to compare the value of linseed meal, cottonseed meal, cold pressed cake and alfalfa hay as sources of protein when fed in connection with sorghum silage. Calves wintered entirely upon silage and a limited amount of feeds rich in protein gained from 1.12 to 1.48 pounds per head daily for one hundred days, at a total cost of feed varying from $7.72 to $7.96 per head. After allowing full market value for the roughest and coarsest feeds that were grown on the farm, and full market value for the labor and bedding used in carrying on experimental work, gains were made at a cost of six cents per pound during the winter and showed a profit when cattle were worth nine cents per pound at weaning time.

Colt-feeding Investigations. In January, 1913, an experiment was started in coöperation with the Kansas State Livestock Registry Board: (1) To determine the efficiency of oats as compared with a ration of corn, bran, and linseed meal in growing draft colts; (2) comparing the rate of development and growth of grade and purebred colts; (3) the cost of production of a horse from weaning time until serviceable. Sufficient time has not elapsed since this project was started to give conclusive results. The studies will be continued.

Chemical Phase of Cream-grading Criteria. Seventy-two samples of butter were analyzed this past year in an attempt to determine the chemical changes which take place in butter made from first and second grade cream when the butter is kept in storage for a considerable time. No direct relation between the chemical changes and the deterioration in the two kinds of butter could be established.

Chemical Phases of Poultry Nutrition. This study was begun in 1913 to investigate the nutritive requirements of chickens.

Preliminary attempts were made to determine the protein requirements and methods of conducting digestive trials. A study was also made of the weakening of bones in young chickens when forced-fed with condensed buttermilk.

Chemical Phases of Dairy-feeding Investigations. During the past two years comparative studies of the nutrients present in silage made from corn, kafir and sorghum have been in progress, also the conditions required for making silage from alfalfa. Complete chemical analyses have been made of corn, kafir and sorghum silage; methods for determining acidity in silage have been perfected; studies in the changes of acidity from time to time have been made; also some of the conditions required for making silage from alfalfa have been determined.

Chemical Phases of Milling Investigation. For several years this station has been studying the baking quality of flour as influenced by such substances as enzymes, the products of protein hydrolysis and electrolytes. Bulletin 190, on "The Influences of Certain Substances upon the Baking Quality of Flour," reports some of the results of this work, and another bulletin is now ready for publication.

Soil investigation on the College Farm. This work has been in progress since 1909, to determine the original fertility in plots used in fertility investigations, and also, to analyze manures and fertilizers used in these investigations. No soil samples and only a few samples of barnyard manure were analyzed in 1913-'14.

Dairy Feeding Experiments. Feeding experiments have been continued to determine the value of sorghum crops for silage, to study the factors influencing the keeping quality of alfalfa silage, and to determine the value of the grain of kafir and corn when fed dry as compared with the grain in silage. It has been proved that sorghum crops can be made into silage with good results.

Cream Grading and Shipping Investigations. Work on this project was started in 1912 for the purpose of establishing a grading system by which cream can be bought for butter-making purposes, according to quality. A grading system has been established and an investigation is now under way to determine the influence of grading on the quality of butter.

Fruit-bud Formation. For several years a study of the conditions most favorable for fruit-bud formation as influenced by pruning, cultivation, fertilizers and protection from fungus has been under way. Fruit buds formed in abundance three years after summer pruning in practically every instance. When pruning was followed by dry weather and cutting back, fruit buds formed in two years. Blotch affecting twigs and young growth is one of the most serious causes of poor fruit formation. Control of this disease has progressed satisfactorily.

Potato Investigations. For three years investigations with potatoes have been under way in coöperation with fourteen growers in the Kaw valley. Seedbed preparation, including rotation and fertilizer studies, variety tests and control of insects and diseases affecting potatoes are the lines of investigation followed.

Grape Investigations. Studies of the form and character of grapevines has been continued, particularly with regard to the amount of old wood best suited for market varieties and test hybrids, possibilities of evenness of ripening by bagging and summer pruning. A great many varieties have been under observation. The indication is that the vines with a larger proportion of old wood do not start so early in the spring and seem less liable to frost injury, less likely to make over-heavy growth of young vines, to require less summer pruning, and are less likely to set a large number of small bunches. Fairly close summer pruning favors evenness of ripening. Ripening was retarded and made more even by bagging.

Poultry Nutrition Investigations. A year ago studies were started to determine for chickens the digestive nutrients and the nutritive value of the common poultry feeds and to secure information concerning the enzymes of the digestive tract of the chicken. The results accomplished have been mostly negative, owing to the great difficulty encountered in getting birds that will give normal results after submitting to an operation for the purpose of separating the excreta of the kidneys from the feces.

Grading of Poultry. A project was started in the fall of 1913 to ascertain the influence of purebred males upon females of mixed breeding and upon the offspring in succeeding generations. Sufficient time has not elapsed since this work

was begun to give results from which definite conclusions may be drawn.

Milling Industry Investigation. The studies which were started in 1910 on the milling and baking qualities of wheat and determination of factors affecting these qualities are still in progress. Sixty samples of wheat from the 1912 crop were milled and baking tests were made, with chemical analyses of the wheat, flour and feed. Similar tests were made on wheat to determine the effect of different methods of handling the crop after ripening. Baking tests were made to determine the effect of fumigants.

Blackleg Investigations. An attempt is being made to standardize blackleg vaccine, prepare serum and produce a more efficient immunizing agent. The vaccine in pill and powder form, serum and aggressin, have been thoroughly tested in the laboratory and upon laboratory animals, and are now ready to test in the field on cattle.

Injurious Mammal Investigation. This project is a continuation of work already well advanced in the eradication of the prairie dog by poison, to encourage the poisoning of the pocket gopher, and to seek more efficient means of destroying moles, rats, mice and other injurious mammals.

OTHER WORK.

Besides the regular work of investigation, the experiment station staff has been doing a considerable amount of control and demonstration work as outlined below:

Control Work.

Pure Seed Control. The botany department is furthering the work in pure seed control by complying with all requests for germination and purity tests of seed samples of the various farm crops, such as corn, kafir, alfalfa, and grass seed. As a result of this work many purchasers have been saved from buying at high prices and planting seed of low vitality, which could be used for feed but would not germinate and produce strong plants if planted. Just previous to harvest during the last ten days of the ripening period of wheat, members of the agronomy and the milling industry departments inspect fields of wheat in order to learn the fields that are pure, and thus to know the sources from which all, pure seed may be obtained by those inquiring for the same at planting time. This work is done in close coöperation with farmers, and is

proving very effective in eliminating mixed and inferior varieties and thus standardizing the wheat crop of the state.

Fertilizer Control. One hundred samples of fertilizers were analyzed within the past year in connection with the enforcement of the fertilizer law.

State Dairy Commission. In 1907 a law was passed establishing the office of state dairy commissioner, whose duty it is to investigate the sanitary conditions of all creameries, public dairies, butter, cheese and ice-cream factories, or other places within the state where milk or cream or their products are handled and sold. As a result of compliance with the provisions of this law the producer and manufacturer are protected and the public is assured pure dairy products of the quality advertised.

Livestock Remedy Law. The food and drug inspector from the Department of Agriculture coöperates with the experiment station in the protection of the consumer and honest manufacturer against fake remedies and high priced nostrums of little remedial value. All condiments and medicines come under this law. Registrations filed disclose cheap ingredients of certain remedies. The work is supported from the sale of revenue stamps.

Feed Control. The departments of milling industry and chemistry have collected and analyzed many samples (1000 in the past year) of concentrated feeding-stuffs and condimental feeds in the work of protecting purchasers against adulterated feeds and condiments. The packages must be labeled according to contents. This is supported by registration fees collected.

State Livestock Registry Board. The State Livestock Registry Board has headquarters at the station. All stallions are examined for soundness, and a record of their breeding is on file in the office of the secretary of the board. Every stallion owner is required by law to secure a license showing the breeding of his animal. The enforcement of this law has resulted in the use of fewer and fewer grade and scrub stallions and more purebreds. The work is supported by money secured from license fees.

Demonstrations.

Dairy. A herd of dairy cows; consisting of the four principal dairy breeds—Jersey, Guernsey, Ayrshire, and Holstein —is maintained at the college. This herd is used for demon-

strational work, class work in judging, and in conducting feeding investigations. In 1910 the average production of butterfat for the herd was 260 pounds. During the year just closed it averaged 498 pounds per cow. One cow produced 19,600 pounds of milk and 837 pounds of butterfat, while seven cows produced an average of more than 700 pounds of butterfat. A cow-testing association was organized by the dairy department in Dickinson county in November, 1913, for the purpose of demonstrating to the farmers of that county that the value of a dairy herd depended more upon the individual animal than upon the dairy breed. A complete record of the performance and the cost of maintenance of every animal was kept. The results obtained conclusively proved to the owners of the animals the value of keeping production records and the cost of maintenance of each animal in order to know which cows were making money.

Entomology. The station entomologist is also a member of the State Entomological Commission. Five thousand dollars is appropriated annually by the state for the use of the commission, one-half of which is spent under the direction of the entomologist of the station and one-half under the direction of the entomologist of the University. This money has been used almost entirely for the control of San José scale. All nursery stock is inspected for scale before it is allowed to be brought into the state. Plantings scattered over 210 miles have been examined, public meetings have been held, and spraying demonstrations given during the year. The members of the entomology department have spent a good deal of time coöperating with farmers in destroying grasshoppers by the use of poisoned bran mash, 100 tons of which was distributed in the summer of 1913, when a severe infestation of grasshoppers occurred. Spraying demonstrations were given in the orchard districts of the state for the purpose of convincing the farmers of the value of spraying their orchards to control insects and plant diseases. As a result of the work done in the summer of 1913, Doniphan county alone purchased more than forty large power sprayers. Eleven counties were completely organized for controlling the chinch bug by burning. The extension division and the agronomy department coöperated with the entomology department in the control work carried on in combating the ravages of the chinch bug.

Horticulture. Other orchard demonstration work has been engaged in by the horticulture department, such as orchard management, pruning, cultivation, and the application of fertilizers. Work in potato rotation, advising communities and individuals regarding improvement of private and public grounds, parks and school grounds has been in progress under the direction of this department.

Veterinary Department. In 1910 the veterinary department undertook the manufacture of serum, the business of which has gradually grown until in 1913 a modern serum plant (fig. 7) was erected at a cost approximating $20,000. Since beginning this work 14,305,744 cubic centimeters of serum

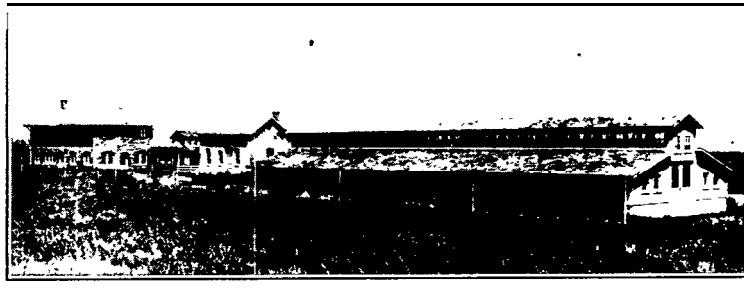

FIG. 6.

have been manufactured and distributed. Five thousand hogs were treated by members of the veterinary department between July 1, 1913, and June 30, 1914. A hog-cholera demonstration was started in Silver Lake township, Pottawatomie county, in the spring of, 1913, to determine the feasibility of controlling hog cholera by the use of virus and serum. The farmers of an area six miles square placed their hogs under the control of the veterinary department. In the brief time this demonstration has been in progress the results have been entirely satisfactory. In one of the most severely cholera-infested areas of the state, and one of the largest hog-growing districts of the state, hog cholera has been brought completely under control. Time will be necessary to determine the practicability of maintaining this desirable condition. A similar demonstration is now being carried on in Marshall county at the request of the farmers, the veterinary department and the Bureau of Animal Industry coöperating.

FINANCIAL STATEMENT.

The Kansas Agricultural Experiment Station, in account with Federal and State Appropriations, 1913-1914.

	Federal Appropriations.	State Appropriations.	Totals.
Manhattan station	$29,995.00	$25,000.00	$54,995.00
Substations	.....	56,453.90	56,453.90
Cooperative experiments	.....	7,500.00	7,500.00
Substation farm products	.....	.....	16,449.12
			$135,398.02
Salaries	$9,296.84	$19,901.45	$29,198.29
Labor	9,068.63	27,951.16	37,919.79
Publications	125.18	162.34	287.52
Postage and stationery	27.19	625.88	653.07
Freight and express	138.97	1,730.99	1,869.96
Heat, light, water, power	158.03	787.80	945.83
Chemicals, laboratory supplies	1,704.51	703.04	2,407.55
Seeds, plants, sundry supplies	1,100.25	4,284.07	5,384.32
Fertilizers	2.08	164.96	167.04
Feedingstuffs	1,588.24	10,517.24	12,105.48
Library	292.83	155.39	448.22
Tools, machinery, appliances	626.62	4,423.23	5,049.85
Scientific apparatus, specimens	2,327.48	201.33	2,528.81
Livestock	401.24	6,527.46	6,928.70
Traveling expenses	996.90	2,566.27	3,563.17
Contingent expenses	20 00	120.44	140.44
Buildings and land	898.81	6,701.83	7,700 64
Furniture and fixtures	321.20	382.81	704.01
Balance	.....	17,495.33	17,495.33
Totals	$29,995 00	$105,403 02	$135,398.02

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Kansas Agricultural Experiment Station for the fiscal year ending June 30, 1914, that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $29,995, and the corresponding disbursements $29,995, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purpose set forth in the acts of Congress approved March 2, 1887, and March 16, 1906.

E. T. HACKNEY.
E. W. HOCH.
CORA G. LEWIS.

Branch Stations of the Kansas Agricultural Experiment Station.

The branch stations of the Kansas Agricultural Experiment Station have been so located that they cover all of the climatic conditions of central and western Kansas, and practically all of the types and classes of soil. The accompanying map gives the location of the stations, describes the soil, and gives the elevation and the average rainfall for each county where the stations are located.

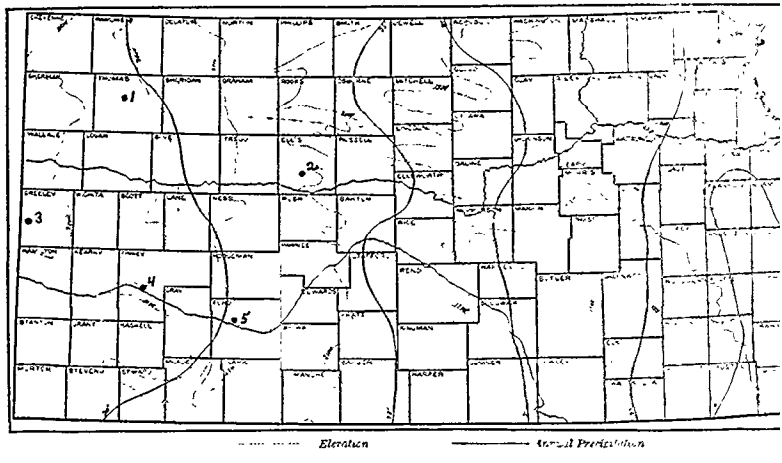

FIG. 7. Map showing location of Kansas branch experiment stations.

1. Colby Experiment Station. Colby silt loam soil, a wind-laid soil, light but rich. Elevation, 3100 feet. Average rainfall, 19 inches.
2. Fort Hays Experiment Station. Summit silt loam soil, a clay soil largely derived from limestone and shales. In many places a shallow soil. Elevation, 2000 feet. Average rainfall, 24 inches.
3. Tribune Experiment Station. Colby silt loom soil (contains more grit than in the area immediately about Colby). Elevation, 3600 feet. Average rainfall, 16 inches.
4. Garden City Experiment Station. Richfield silt loam soil, an alluvial soil containing considerable grovel and sand; derived largely from crystalline rocks. Elevation, 2800 feet. Average rainfall, 19 inches.
5. Dodge City Experiment Station. Hamilton soils, medium to heavy, rich in lime, extremely variable. Elevation, 2300 feet. Average rainfall, 21 inches.

From this map it will be seen that any local agricultural problem arising in central or western Kansas can be practically duplicated on some one of the experiment farms. The work of each station is planned and carried on with a view to meeting and solving the average farmer's problems, thus saving the farmer the expense of trials in growing unadapted crops or of unprofitable practices.

The Department of Agriculture is coöperating with the state n carrying on the dry-land-farming investigations at the Hays, Garden City and Colby stations. In this coöperative work the government pays the salary of the man directly in charge of the experiments, and the state furnishes the land, all seed used in planting, and the implements and teams necessary to properly handle the crop. At three branch stations similar government cooperative work is being done, and is under way at sixteen other government or state stations of the Great Plains area of the United States.

This coöperative dry-land work covers definite crop rotations, ranging from continuous growing of one crop year after year on the same land to the same crop alternating with summer fallow and to six-year rotations which include both summer-fallow and green-manure crops. Some of these plots are regularly prepared with early and deep plowing or listing, others with early shallow plowing or listing, others with late deep plowing or listing, while others are prepared with late shallow plowing or listing. Some are regularly prepared in the best manner known, considering moisture conditions. Others in direct comparison are prepared according to the average farm practice of the neighborhood, and records are being kept of the resulting yields.

In addition to this rotation and soil-handling work, extensive variety tests are conducted with all crops grown in the state. On a limited scale any new crops that show a possibility of proving valuable are given a careful and fair chance to prove their worth. Each station supplies to the farmers of its respective region, so far as it is able, pure seed of adapted crops at prices only a little above market feed prices. The superintendent of each station keeps posted as to where pure seed of the standard crops can be secured if he is unable to supply it himself.

A statement regarding the special work of each station follows:

FORT HAYS BRANCH EXPERIMENT STATION.

The law establishing the Fort Hays Branch Experiment Station was passed in 1900, and reads as follows: "The state of Kansas hereby accepts from the United States the abandoned Fort Hays military reservation in said state for the

purpose of establishing an experimental station of the Kansas State Agricultural College . . . and a public park." The experiment station comprises approximately 4000 acres, located in Ellis county, a portion of the land being rich creek-bottom land and the balance upland silt loam. The elevation approaches 2000 feet, while the average rainfall is 22.52 inches each year.

The work of the station is both investigational and demonstrative. Coöperative investigational work is carried on with the United States offices of Cereal-crop Investigations, Dry-land Agriculture and Forage-crop Investigations. Investigational and demonstrative work with dairy and beef cattle, hogs and general field crops is maintained. The dairy barn and herd are depicted in figure 9. Representative herds of the

FIG. 8.

four principal breeds of beef cattle—Shorthorns, Herefords, Angus and Galloway—are kept, the entire herd averaging between 450 and 500 head.

Range Cattle Feeding. The beef cattle are handled under range conditions, and are fed, in addition to silage, the by-products ordinarily obtained on a Kansas farm, viz., kafir stover and wheat straw. Tests are in progress to determine the best protein concentrates for use with these feeds. The most economical ration that will keep the growing or breeding stock in good condition is being sought by every progressive stock farmer. The Fort Hays Station has partially solved this problem for western Kansas. In the following test three com-

binations of feeds are shown, each of which is considerably cheaper, more efficient and more easily obtained on the average farm than the rations in more common use:

WINTERING BEEF CATTLE.

November 25, 1913, to April 9, 1914.

	Lot VII. Dry lot.	Lot VIII. Dry lot.	Lot IX. Open range.
	Kafir fodder, Wheat straw. Kafir silage. Cottonseed cake.	Kafir fodder, Wheat straw. Kafir silage. Linseed meal. Alfalfa.	Kafir fodder. Wheat straw. Kafir silage. Cottonseed cake.
	No. Cows. *Lbs.*	*No. Cows.* *Lbs.*	*No. Cows.* *Lbs.*
Initial weight	20 22,423	22 23,144	21 22,830
Final weight	20 22,795	22 24,370	21 23,805
Average daily gain of entire lot	2 73 lbs.	9 lbs.	7.17 lbs.
Average daily ration:	*Lbs.*	*Lbs.*	*Lbs.*
Kafir fodder	243	264	155
Wheat straw	182	189	89
Kafir silage	108	113	110
Cottonseed cake	20	000	19
Linseed meal	000	21	000
Alfalfa	000	12	000
Total feed consumed:	*Lbs.*	*Lbs.*	*Lbs.*
Kafir fodder	33,077	35,940	21,127
Wheat straw	24,776	25,660	12,223
Kafir silage	14,735	15,350	15,076
Cottonseed cake	2,815	000	2,718
Linseed meal	000	2,984	000
Alfalfa	000	1,705	000
Total value of feed	$114.04	$135 78	$95.20
Total amount of feed per animal:	*Lbs.*	*Lbs.*	*Lbs.*
Kafir fodder	1,654	1,663	1,006
Wheat straw	1,238	1,166	582
Kafir silage	737	702	717
Cottonseed cake	140	000	129
Linseed meal	000	135	000
Alfalfa	000	77	000
Total value of feed per animal	$5.70	$6.17	$4.53
Labor value per animal for winter	1.94	1.85	1.94
Total cost of wintering	7.64	8.02	6.47
Number of cows aborting	3	0	2
Feed values:	*Feed values:*		
Alfalfa hay $8.00 per ton.	Kafir fodder $2.00 per ton.		
Kafir silage $4.00 per ton.	Wheat straw $1.00 per ton.		
Linseed meal $1 54 per cwt.	Cottonseed cake $1.39 per cwt.		

Other feeding tests of this same nature have been made with mature breeding cows and with fattening steers. The results of most of these tests have already been made public. Figure 10 gives a partial view of the feeding sheds at this substation.

Hog Feeding. Two carloads of market hogs are produced and sold each year, with feeding investigations during the growing and fattening periods.

Sheep Feeding. A flock of 125 to 150 sheep is maintained on the station land and handled under western farm conditions. It is fed principally upon the by-products of the wheat farm.

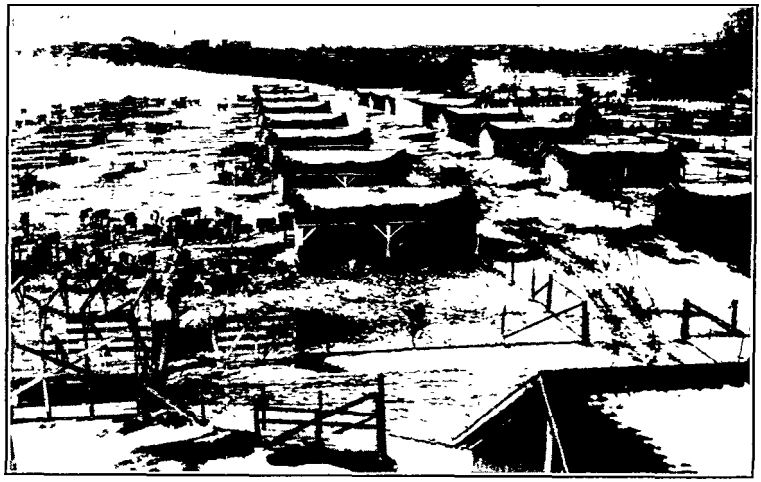

FIG. 9.

Forestry. A large forest-tree nursery has been started on the station, the trees from which are sold at actual cost of production. About one-half million trees have been thus distributed.

Seed Distribution. Considerable quantities of pure seed wheat and kafir are sold at market price for seed purposes. Since the establishment of the Hays station it has distributed for planting purposes more than 1000 bushels of seed corn, 10,000 bushels of seed wheat, enough kafir seed to plant 22,400 acres, enough milo to plant 5000 acres, and enough sweet sorghum to plant 3300 acres.

Cereal Grain Investigations. The Fort Hays Station has developed to its present excellent state the White-hulled White kafir, which has proved to be the best variety for central western Kansas. It has also developed the Western Orange sorghum, which is the best sweet sorghum for that locality, and has assisted in developing Dwarf kafir. In the cereal investigations from 300 to 350 strains and varieties are tested annually. At the present time a large part of the wheat in western Kansas is from seed originally distributed by the Fort Hays Station.

Forage-crop Investigations. In the forage-crop investigational work approximately 225 varieties, strains and selections are under study, while in the coöperative work with the Office of Dry-land Agriculture sixty-one tillage, rotation and fertilization experiments are under observation.

GARDEN CITY BRANCH EXPERIMENT STATION.

The Garden City Branch Experiment Station was established in 1907 "for the purpose of carrying out experimental and demonstration work adapted to the climatic and soil conditions of southwest Kansas." The station is located on the high upland four and one-half miles northeast of Garden City, Finney county, Kansas. The station land consists of 320 acres. This is leased by the county commissioners of Finney county to the Board of Regents of the State Agricultural College, the lease being dated June 14, 1907, and running for a period of ninety-nine years. The soil is classified as Richfield silt loam, and is rich in lime but lacks in vegetable matter. The soil is of such a nature that it does not absorb moisture readily.

Coöperative Work with the Government. From the time of the establishment of the station, coöperative work with the Department of Agriculture has been performed in dry-land experiments. The nature of this coöperative work is largely soil preparation and rotation of crops. In connection with these experiments climatological records are taken daily, showing the precipitation, maximum and minimum temperatures, wind velocities, humidity, and intensity of the sunlight. These data are compared each year with similar records taken at the other stations with which the Department of Agriculture is coöperating. Such climatological data, covering the area from Canada to Mexico and from the ninety-eighth meridian to the Rocky Mountains, allows a very accurate correlation to be made between weather conditions and crop yields.

Deep-well Pumping Investigations. Beginning with the year 1912, the Garden City Station has been coöperating with the Office of Experiment Stations in carrying on investigational work with deep-well pumping plants. Realizing that the future development of western Kansas uplands for farming purposes depends upon the practicability of deep-well irrigation, this work is being made the principal line on the Garden City Station. The county commissioners of Finney county and the Commercial Club of Garden City provided funds for the in

stallation of the deep-well pumping plant, at a cost of approximately $6200. At present, there is very little information available covering the requirements of deep wells such as it is necessary to put in over much of western Kansas. Manufacturers of many pumps guarantee their product for special conditions of lift and speed, but the conditions of the guarantee are not found in many of the wells where the pumps are actually installed. Various tests of the types of pumps now in use are being made and their performance charted. Such data will be of great and immediate use to the farmers of this locality in selecting types of pumps adapted *to* their conditions.

Irrigation Investigations. In addition to the problem of the pumping plant itself, irrigation experiments are being conducted to determine the proper time and proper quantity of water to apply to the various crops under the conditions of this locality. An earth reservoir holding 2.5 acre feet of water has been completed, and measurements are being made to determine the loss from seepage and evaporation. Work will also be conducted to determine the loss that takes place in conveying water in an open ditch from the pumping plant to distant fields.

Variety Tests. Paralleling the foregoing work, which is carried on in coöperation with the Department of Agriculture, the station is conducting variety tests of the sorghum crops, corn and small grains. It is also handling on a farm scale five irrigated fields. Up to the present time the conclusions on this work are that under existing farming conditions in Finney county the sorghums are the surest and most dependable field crops that can be grown. Small grains, on ground of average preparation, are not profitable. It is as important to handle the ground in such a manner that any moisture which falls will be readily absorbed as it is to attempt to conserve moisture already stored by preparing a soil mulch. With any of the soils of western Kansas, other than those which are practically pure sand, proper cultivation will prevent blowing.

The total value of equipment, including pumping plant and buildings, at the Garden City Station is $10,700. Of this amount $725 is credited to live stock.

TRIBUNE BRANCH EXPERIMENT STATION.

The establishment of the Tribune Branch Experiment Station was provided for by the legislature of the state of Kansas during the 1910-'11 session. The station is located about two miles southwest of Tribune, Greeley county, Kansas. It has an altitude of approximately 3625 feet, is 38° 28' north latitude and 101° 46' west longitude. This places the station in central western Kansas and fifteen miles from the Colorado line. The average rainfall is 16 inches. The altitude and latitude combined with the light rainfall makes this locality of as short growing season as any part of Kansas. The soil, although classified as Colby silt loam, contains more grit than the soil about Colby. It also contains a smaller amount of humus. The depth to water on average upland varies from 100 to 175 feet.

The station land, consisting of about 110 acres, was deeded to the state by George L. Reid, a progressive and enterprising citizen of Tribune.

Local Problem. The purpose of the station is similar to that of the other stations, but gives particular attention to local problems. By numerous experiments the station is finding and will continue to find the varieties and strains of crops that are best adapted here. It will also work out the methods of seedbed preparation and crop handling that are most economical and most practical. The station has proved to the satisfaction of all near-by farmers that it is possible to handle soil of this character, even under summer fallowing, without blowing.

Variety Tests. In the last three years twenty-five varieties and strains of corn, more than thirty varieties of sorghums and about the same number of varieties of other crops have been tested. Small tests have also been made with Mexican and Tepary beans, Spanish peanuts, sweet clover and alfalfa in rows. The station first introduced feterita and Sudan grass to this part of Kansas, and grows pure seed of adapted crops for general distribution.

The Sorghums and Kafir. Although there are some who believe that extreme western and northwestern Kansas can not successfully grow kafir or any of the sorghums for grain purposes, the Tribune Station has regularly produced paying

yields of these crops. During the season just past, with a rainfall of approximately ten inches during the growing season, the following yields were secured:

	Grain per acre.	Forage per acre.
Dwarf kafir on fallow.....	12 bu.	6,000 lbs.
Dwarf kafir continuously cropped.....	No grain	1,500 "
Freed sorghum on fallow.....	18 bu.	3,000 "
Sudan grass on fallow.....	.....	8,000 "

Seed of these adapted varieties is being sold to the farmers of Greeley county and near-by country.

Further Plans. In order more fully to utilize the rough crops produced, and in order to conduct the farm on a more logical basis, the station expects to purchase and maintain about one-half dozen milk cows. A pit silo will also be constructed as this offers the cheapest and most economical means of storage for rough feed crops.

COLBY BRANCH EXPERIMENT STATION.

The Colby Branch Experiment Station was located in December, 1913, and work started March 1, 1914. "The purpose of the station is to advance the agricultural, horticultural and irrigation interests of the state and of western Kansas," to develop and promote good farm practices, particularly encouraging the livestock industry, to aid in bringing under general use the crops best adapted to that part of the state, and to assist in distributing pure seed. The station is located on upland one-half mile southwest of Colby, in Thomas county. Both the Rock Island and the Union Pacific railroads pass through Colby, and the Golden Belt, Red Line, and Rock Island Highway Auto roads run along one side of the experiment farm. This makes the station easily available for inspection by most of the people of northwest Kansas.

The station land consists of 320 acres, purchased by Thomas county at a cost of $10,000 and deeded to the state of Kansas so long as it shall be used for an experiment farm. The soil is of the Colby silt loam, very fine, well supplied with phosphorus and lime. It contains practically no sand or grit, and is rather deficient in humus. It is a type of soil that blows easily, but is very fertile when supplied with sufficient moisture. Abundant and good water is obtained at a depth of 110 to 130 feet.

General Work. In addition to the dry-land work already mentioned, which is carried in coöperation with the Depart-

ment of Agriculture, the station will conduct variety tests with all crops that give promise of being of value in northwest Kansas.

Pumping Plant. When the station was established an appropriation was provided for sinking a well and installing a small pumping plant. This plant will irrigate a small patch of five or ten acres of alfalfa that will produce feed even in the driest years, and thus serve as insurance against failures. When work was started on these wells very little was known regarding the stratas of soil or sand to be encountered. The state has done the experimenting, and the first wells have cost more than another set of similar wells will in the same locality.

There are two wells, 151 and 159 feet in depth. Both are ten-inch holes for the first 130 feet, and nine inches to the bottom of the wells. The first water was encountered at 112 feet, and there are intervening layers of fine sand, coarse sand and clay from that depth to the bottom of the well. There is an average of about thirty feet of water-bearing sand and gravel in each well. By actual test, the wells each have a capacity of seventy-five gallons per minute, working on a twenty-inch stroke and thirty-four strokes per minute. The wells are now equipped with an eight-horsepower oil-burning Fairbanks-Morse engine. A line shaft connects both wells to the one engine. The pumps are of ordinary deep-well tubular type, equipped with 5.75-inch brass-lined cylinders and ball check valves. The pump heads are of ordinary pump-jack type, capable of either sixteen or twenty inch stroke. In short, the entire pumping plant is the most simple that could be secured. The initial cost is comparatively low, considering the depth of wells and the amount of water lifted. The pumping plant complete is of such a type that it can be handled by any farmer, provided he can operate successfully an ordinary gas engine.

Fruit. Ten acres of the experiment farm are set in orchard. The body of the orchard is set in apple, cherry, plum and apricot trees, with a few peach trees. There is a protective border of cedar, mulberry and locust trees on all sides of the orchard. The station expects to irrigate one-half of this orchard and handle the balance under dry-land methods. By good culture, proper pruning and spraying, and by the planting of varieties

of trees that are adapted to the existing conditions, it is expected to show that the farmer can produce on his own farm (at an expense below the cost of purchasing) all the fruit that his family needs during the summer season and enough to fill the cellar for winter use.

Control of Soil Blowing. Another important work of the station is to demonstrate that soil blowing can be prevented on land of this type. During the last season, besides preventing blowing on the station farm, the superintendent looked after the handling of an additional 400 acres in the "blown area." The corn produced on 160 acres of this area was 1400 bushels. Another 160 acres was equally productive in sorghums, although definite yields were not measured, as the crop was harvested by several parties.

Future Plans. Every farm in this part of the state should grow enough livestock to consume the rough feeds (principally sorghums) which this country produces so abundantly. With this purpose in view, the station will purchase a small dairy herd and maintain it for demonstration purposes and for the profit that it gives. In addition to these lines of work, variety tests of small grains, sorghums, corn and other crops will be conducted. During the season just past (the first year of the station) variety tests were carried on with eleven varieties of sorghum and ten varieties of corn. Some small tests were also made with other crops.

DODGE CITY BRANCH EXPERIMENT STATION.

The Dodge City Branch Experiment Station was established as a forestry station a number of years ago, but was reorganized, and the experiment station was given control in 1909. The station is located three and one-half miles northeast of Dodge City, Ford county, Kansas. The farm consists of 160 acres, seventy acres of which is in native pasture. The soil is upland and of the Hamilton series. It is rather heavy, yet handles fairly easily. Abundant water is obtained at about 100 feet. The main line of the Santa Fe railroad, a branch of the Rock Island, and the Dodge City and Cimarron Valley railroad run into Dodge City. The Santa Fe Trail auto line also runs through Dodge City. This makes the Dodge City Station easily available for inspection by most of the people of southwest Kansas.

Dairy Cattle. Besides following out in a general way the same lines of work that are carried on the other stations, this station has since 1911 been developing a herd of good dairy cows from the average grade stock of the community. The work was started with six mixed grade cows and a purebred Ayrshire bull. The cows were average stock, such as is commonly used for dairy work in that part of the state. By testing and weighing the milk it was discovered at once that one of the cows did not pay for her feed. Two others were of decidedly common quality. By using a purebred bull on these cows the station expects to prove to the farmers that a good and paying dairy herd can be built up. The first two heifers from this purebred bull have freshened recently. Records so far secured indicate that they will be much better milk cows than their mothers. It will take at least four years longer to satisfactorily complete the work, but already the dairy is returning a very nice profit. During the fiscal year closing June 30, 1914, sales from this station (160 acres) totaled $1283.59. Largely on the skim milk from the dairy, the station is growing a few hogs each year. The sales of these hogs during the last year amounted to $148.30.

Variety Tests. During the past season variety tests were conducted with thirteen varieties of sorghum, five of alfalfa, eleven of wheat, and two of oats, besides several less important crops. The results of these sorghum tests have checked up very closely with the results secured on the station at Hays. Red Amber and an early strain of Orange sorghum make the best forage yields. The season has not been long enough profitably to grow Sumac sorghum. Freed sorghum, Dwarf kafir, Dwarf milo, and feterita have proved the best. White-hulled kafir is also good. In the work with wheats it is interesting to note that an average yield of the pedigreed strains of wheat sent out by the agricultural college at Manhattan has been above the average yield of the other varieties tested.

Bindweed Eradication. The bindweed (also called the perennial field morning-glory) is becoming a dangerous weed pest in many Kansas counties. The Dodge City station is attempting to determine the most practical way to rid a field of these weeds. This work includes the use of smother crops, such as broadcast sorghums; summer fallow and other clean culture

methods; hoeing; and applying salt at various rates. The work is not yet conclusive, but it is certain that the weed can not be killed by any ordinary method in a single year. Hoeing is too expensive to be practical. Salting has been the most satisfactory to date. Another two years should provide a solution for the problem.

THE INFLUENCE OF THE TIME AND METHOD OF PREPARING THE SEEDBED UPON THE YIELD OF WINTER WHEAT.

BY L. E. CALL.

The particular method of seedbed preparation for winter wheat influences markedly the conservation of moisture, the liberation of plant food, and the growth of the crop. A number of investigators have worked upon this problem. The Michigan station,[1] in bulletin 181, reports 20 percent increase in yield of winter wheat by early plowing as compared with late plowing. Arkansas[2] showed that thorough preparation of the seedbed, as compared with poor preparation, increased the yield of wheat 50 percent. It also diminished the injurious effects of drouth. Oklahoma[3] indicated that ground plowed during the middle of July produced a five-year average of 27.1 bushels per acre, while ground plowed during the middle of September produced 22.1 bushels. The Utah station[4] compared different depths of plowing in preparing ground for winter wheat under arid conditions. After five years' tests on four different farms the following average yields were obtained:

Plowing 8 inches deep	13.7 bushels per acre
Plowing 10 inches deep	14.0 bushels per acre
Plowing 15 inches deep	13.4 bushels per acre
Plowing and subsoiling 18 to 20 inches deep.....	13.3 bushels per acre

The effect of the preparation of the soil upon the conservation of soil moisture or liberation of water-soluble plant food was not reported in any of these investigations.

The North Dakota station[5] in the production of spring wheat secured, as an average yield for seven years, one bushel more

1. Michigan Experiment Station Bulletin No. 181.
2. Arkansas Experiment Station Bulletin No. 62.
3. Oklahoma Experiment Station Bulletin No. 65.
4. Utah Experiment Station Bulletin No. 112.
5. North Dakota Experiment Station Bulletins Nos. 29, 38, and 48.

wheat from fall than from spring plowing. The fall-plowed ground contained more moisture at the time of seeding than the spring-plowed ground. The Nebraska[6] and Montana[7] stations have shown that by preparing a seedbed for winter wheat by summer tillage water is stored in the soil and held by cultivation until needed by the crop. King[8] of the Wisconsin experiment station discovered that fall and early spring plowing favor the conservation of moisture and the development of nitrates, but the resulting effect upon the growth of winter wheat was not determined. Quiroga[9] found in the preparation of a seedbed for corn in an abnormally dry year in Ohio that the moisture content of the soil remained higher throughout the summer on land plowed in April than upon June-plowed ground. He also showed that for the entire season the available nitrogen in the surface foot of soil on the early-plowed ground was twice as great as on the late-plowed ground. King and Doryland[10] have shown that deep plowing tends to increase the number of bacteria in the soil and to increase bacterial activity, but the effect of the depth of plowing upon nitrification was not shown.

PRELIMINARY TEST.

Investigational work for the purpose of determining the influence of different methods of preparing the seedbed upon the yield of wheat was first outlined at this station in 1907. The field upon which the work was started, although apparently uniform in character, proved to be altogether too ununiform for satisfactory experimental work. This lack of uniformity was caused by variations in the depth of underlying rock, which, although not coming within six feet of the surface, approached it near enough in places to influence the yield and to make any study of moisture conditions under different soil treatments untrustworthy.

This field had been in alfalfa for a number of years. The alfalfa sod was broken two years before the work was started. The first season after breaking the field was in corn and the second season in wheat. While conditions were unfavorable

6. Nebraska Experiment Station Bulletin No. 114.
7. Montana Experiment Station, Bulletin No. 87.
8. Annual Report Wisconsin Experiment Station, 1901.
9. Modesto Quiroga's Master Graduating Thesis, Ohio State University, 1914.
10. Kansas Experiment Station Bulletin No. 161.

for satisfactory experimental work upon this area, the results of the work are interesting as indicating in a general way the effect of different methods of preparing the seedbed upon the yield of wheat. Yields for the two seasons during which this work was carried on were as follows:

TABLE 1. Soil treatment and yield of wheat, 1908 and 1909.

Plot No.	Method of preparation.	Yield of wheat, bushels per acre.	
		1908.	1909
1	Double disked middle of July; plowed 7 inches deep middle of September	27.24	35.11
2	Check; plowed 7 inches deep, middle of September	26 72	32.53
3	Listed middle of July, worked frequently after listing	25.05	36 21
4	Listed middle of July; ridges split with lister middle of August; worked frequently after listing	26.59	34 85
5	Check; plowed 7 inches deep middle of September	20.40	30 99
6	Plowed middle of July, 7 inches deep; worked frequently after plowing	*28 27	*36 21
7	Plowed middle of September, 3 inches deep	19 24	30.14
8	Check; plowed 7 inches deep middle of September	16 27	25.56
9	Plowed middle of August, 7 inches deep; worked frequently after plowing	30 98	36.79
10	Plowed middle of August, 7 inches deep; not worked until middle of September	26 34	33.89
11	Check, plowed 7 inches deep, middle of September	14 98	22.85
12	Plowed middle of July, 3 inches deep; worked frequently after plowing		38.34

* Wheat lodged badly, especially in 1909.

The lack of uniformity of the soil caused a great variation in the yields between the check plots in the different parts of the area. The work, nevertheless, shows that a marked increase in yield has resulted on those plots where the ground was worked early in the season. The comparatively low yield upon the plot plowed in July seven inches deep resulted from too rank growth of straw which caused the wheat to lodge badly, thus reducing the production of grain. Although the weight of the straw was not obtained, much more straw was produced upon this plot than upon any other in the test. The rank growth of straw undoubtedly resulted from an extensive development of nitrates upon this early-plowed plot, due to the frequent cultivations of a soil recently in alfalfa, which was well supplied with easily decomposed nitrogenous matter. This indicates a danger in preparing ground for wheat which may result from too early plowing and too extensive cultivation upon highly fertile soils well supplied with moisture.

FURTHER TESTS.

In order to secure a more uniform soil, a new location was obtained in the fall of 1909. The area devoted to this work consists of about two acres, located upon the agronomy farm two and one-half miles northwest of Manhattan. The ground is low upland, occupying a position some fifty feet above the

Kansas river valley, but at the same time it is much lower than the high prairie. The area slopes gently to the south and east, but is comparatively level. The accompanying contour map (fig. 11) shows the topography of the area.

THE SOIL.

The soil is a loessial formation, classified as Marshall silt loam.[11] This is a common type throughout northeastern Kansas, being a dark-brown silty loam about ten inches deep. The subsoil to a depth of six feet is reddish-brown silty clay loam. The upper portion of the subsoil contains more clay and is quite plastic, but the content of fine and very fine sand increases with depth, so that in the fifth or sixth foot the subsoil contains a considerable quantity of the finer grades of sand. As a rule, the soil is retentive of moisture and is not quickly affected by dry weather. The soil shows some variation over the area. The south soils are slightly heavier, darker and more plastic than those at the extreme north end. Starting with the south side of the plots, the soil gradually grows lighter in texture toward the north. Plot 1 represents the heaviest, and plot 15 the lightest soil. This condition is most noticeable in the subsurface soil.

The following table gives the mechanical analysis of the soil on plots 1 and 15. The analysis is shown for each foot to a depth of three feet:

TABLE 2. Mechanical analyses of soils on plots 1 and 15.

Plot.	Depth in feet.	Percent of fine gravel.	Percent of coarse sand.	Percent of medium sand.	Percent of fine sand.	Percent of very fine sand.	Percent of silt.	Percent of clay.
1	0-1	0.03	0 25	0 46	1.20	8.20	64.67	23.59
15	0-1	0 07	0 46	0.56	3 46	12 62	58.01	23.73
1	1-2	0 00	0 18	0 57	1 25	5.59	54.49	36.01
15	1-2	0 12	0 46	0.55	3 72	12.55	50.53	30.59
1	2-3	0 02	0 13	0.22	0 84	6 78	56.63	33.91
15	2-3	0 34	0 90	0 87	6 31	16 04	48.29	26.41

The smaller amount of silt and clay and the larger amount of fine and very fine sand in the subsoil of plot 15 as compared with plot 1 will account for the difference in moisture equivalent as indicated below.

11. Soil Survey, Riley County, Kansas. Bureau of soils, U. S. Department of Agriculture.

The moisture equivalent, or the percent of moisture that the soil will retain when saturated and subjected to a centrifugal force one thousand times that of gravity, was obtained for each foot to a depth of six feet on plots 1 and 15. The moisture equivalent and wilting coefficient as determined were as follows:

TABLE 3. Moisture equivalent and wilting coefficient of soil to a depth of six feet on plot 1 and plot 15. [12]

Depth.	Plot 1.		Plot 15.	
	Moisture equivalent.	Wilting coefficient.	Moisture equivalent.	Wilting coefficient.
1 foot	23.0	12.49	22 5	12 22
2 feet	26.5	14 39	21 5	11 67
3 feet	25 9	14 06	24 9	13 52
4 feet	26 3	14 28	25 4	13 79
5 feet	21.7	11.78	21 8	11 84
6 feet	21 3	11 56	21 3	11 56
Average 4 feet	25 4	13 80	23 5	12 80

(12) Determinations made in the office of Dr. Lyman J. Briggs, Bureau of Plant Industry, U. S. Department of Agriculture

These determinations show that plot 1, which has the heavier type of soil, has the higher moisture equivalent and also the higher wilting coefficient. The difference in wilting coefficient of the surface four feet of soil is exactly one per-cent between the two plots. If the change is a gradual one from plot 1 to plot 15, the difference in the wilting coefficient of the soil to a depth of four feet would be .07143 percent less for each plot from plot 1 toward plot 15. Using this factor, the wilting coefficient of the soil in the surface four feet of each plot as follows:

Plot.	Wilting coefficient.	Plot.	Wilting coefficient.
1	13.80%	9	13.22%
2	13.73	10	13.16
3	13.66	11	13.08
4	13.59	12	13.01
5	13.51	13	12.94
6	13.44	14	12.87
7	13.37	15	12.80
8	13.30		

PREVIOUS CROPPING.

The exact history of the cropping of the area is not known. It has undoubtedly been under cultivation for nearly thirty years and cropped continuously to grain crops. From 1898 to

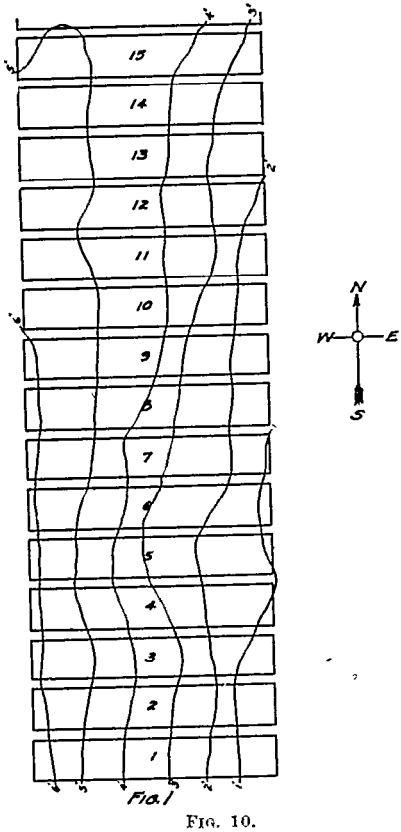

FIG. 10.

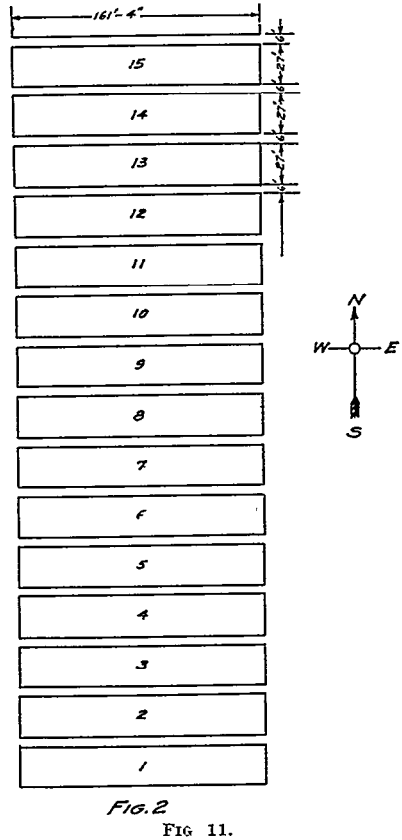

FIG 11.

1908 the field grew kafir and sorghums most of the time. As far as known, no leguminous crops have been grown and no fertilizer, manure or other fertilizing material applied. In 1907 the field was in kafir and produced a very light crop. In 1908 the field was in corn and produced a yield of less than five bushels per acre. In 1909 the field was in oats. The field in the past has been plowed shallow and poorly farmed.

METHOD OF PLOTTING.

The area devoted to this work is subdivided into fifteen plots, cropped continuously to wheat. Each plot is 1611/3 feet long and 27 feet wide, making an area of one-tenth of an acre. The plots are separated by an alley six feet wide, and are numbered from 1 to 15 from south to north. Figure 12 shows the method of plotting and numbering.

TREATMENT OF THE PLOTS.

The area was cropped continuously to wheat and the seedbed prepared each year as follows:

PLOT 1. Not plowed. Wheat stubbed in by disking just before seeding and seeded with disk drill.

PLOT 2.[13] Check. Plowed September 15, seven inches deep.

PLOT 3. Double disked July 15. Plowed September 15, seven inches deep.

PLOT 4. Double disked July 15. Plowed August 15, seven inches deep.

PLOT 5.[13] Check. Plowed September 15, seven inches deep.

PLOT 6. Listed July 15. Ridges worked down.

PLOT 7. Listed July 15. Ridges split August 15 and ridges worked down.

PLOT 8.[13] Check. Plowed September 15, seven inches deep.

PLOT 9. Plowed July 15, seven inches deep.

PLOT 10. Plowed August 15, seven inches deep.

PLOT 11.[13] Check. Plowed September 15, seven inches deep.

PLOT 12. Plowed August 15, seven inches deep. Not worked down until September 15.

PLOT 13.[14] Plowed September 15, three inches deep.

PLOT 14.[13] Check. Plowed September 15, seven inches deep.

PLOT 15. Plowed July 15, three inches deep.

Each plot was prepared for wheat in the same way each year, the effect of the treatment thus being cumulative. All plots with the exception of No. 12 were worked in the best possible manner after plowing. All were seeded with a disk drill, sowing crosswise of the plots. Bearded Fife semi-hard red winter wheat was sown at the rate of one and one-fourth bushels per acre.

THE COST OF PREPARING LAND FOR WHEAT.

An attempt has been made to determine approximately the cost of preparing the seedbed for wheat by each of the methods of treatment employed. It was not considered advisable in figuring the cost to use the actual cost of work as performed on the small plots, but rather to use a stipulated charge for each operation, and thus to determine the cost by the number of different operations necessary during the season. In figuring the cost, the charge for labor was taken arbitrarily as follows:

Plowing seven inches deep.	$1.75 per acre
Plowing three inches deep	1.25 per acre
Listing	.75 per acre

13. Plowed three inches deep after 1911.

14. Plowed seven inches deep after 1911.

Double disking	.80 per acre
Single disking	.40 per acre
Acme harrowing	.35 per acre
Harrowing (spike-tooth)	.25 per acre
Seeding	.40 per acre

In some cases these figures may be too high and in other cases too low, but as the same figure has been used in computing the cost on the different plots, it will at least be comparable. A factor not taken into consideration in estimating cost, particularly of plowing and listing, has been the condition of the soil with respect to moisture at the time this work was done. It might in certain cases cost more to plow a dry soil three inches deep than a moist soil seven inches, but the variation from year to year in the condition of the soil at any particular date of plowing will to some extent reduce this error. The following table gives the cost of preparing the seedbed for each treatment for the seasons 1909 to 1912, inclusive, and the average cost for the four years:

TABLE 4. Cost of preparing land for wheat.

Plot.	Treatment.	Season of 1909-'10.	Season of 1910-'11.	Season of 1911-'12.	Season of 1912-'13.	Average cost for 4 years.
1	Disked; not plowed	$2.85	$1.95	$2.25	$2.00	$2.26
3	Disked July 15; plowed Sept 15, 7 in. deep	3 95	4.35	3.85	3.70	3.96
4	Disked July 15; plowed Aug. 15, 7 in. deep	4.60	4.70	5.35	4.35	4.75
6	Listed July 15; worked down	3.05	3.70	5.10	2.95	3.70
7	Listed July 15; ridges split Aug. 15	2 90	3.75	4.30	3.30	3.56
9	Plowed July 15, 7 in. deep	4.00	4.95	6.25	4.85	5.01
10	Plowed Aug. 15, 7 in deep	3.80	3.90	4.55	3.55	3.95
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	3.15	3.55	3.55	2.90	3.29
2	Plowed Sept. 15, 7 in. deep	3 15	3.55	3.55	3.90	3.29
13	Plowed Sept. 15, 3 in. deep	2.65	3.05	3.05	2.40	2.79
15	Plowed July 15, 3 in deep	3 50	4.45	3.75	4 35	4 01

In the preparation of the plots no attempt was made to prepare a seedbed in the cheapest manner, but rather to prepare the best seedbed possible, regardless of cost. Thus the plots plowed in July and August were worked as often as necessary to keep down weed growth and to maintain a soil mulch. The plots plowed in September were worked sufficiently to make them the best possible under the conditions. The amount of

work necessary to prepare a good seedbed and to keep the soil in good condition varied from season to season, due to differences in weather conditions. Thus, in 1909 it was possible to prepare a good seedbed for $4 an acre on ground plowed seven inches deep in July, while it cost $6.25 to prepare an equally good seedbed in the summer of 1911.

METHOD OF SAMPLING FOR MOISTURE AND NITRATES.

Moisture samples were taken nearly every season on all plots at the time of the first preparation work, or about July 15. Additional samples were taken August 15, September 15, at about seeding time in October, at the time when growth started in the spring, and again at the time of harvest. The samples taken July 15 usually represented conditions at harvest time. Nitrate samples were taken at seeding time in the fall, at the beginning of growth in the spring, and at harvest. Moisture samples were taken regularly to a depth of four feet and nitrate samples to a depth of three feet, except at the time of seeding in the fall and at harvest in the spring, when the moisture samples were usually taken to a depth of six feet. A one-inch steel tube was used to take the samples. Duplicate samples were taken for both moisture and nitrate determinations. The samples were taken in sections of one foot and the moisture and nitrate determinations made on each foot of soil separately. The moisture samples were weighed and dried in the sample box in which the samples were taken in the field. In this way the moisture in the entire sample was secured. The samples were dried in an air-bath oven heated by gas and were dried to constant weight at a temperature of 105° C.

Separate samples were taken for the nitrate determination. The samples were taken with a steel soil tube, and each sample consisted of a composite taken at five different points on the plot as shown by the accompanying diagram.

Method of Taking Soil Samples for the Determination of Nitrates.

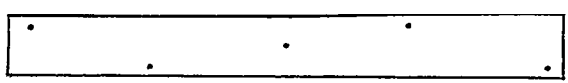

FIG. 12.

* Points on the plot at which samples were taken.

The samples were brought to the laboratory and worked up as rapidly as possible. Duplicate determinations for nitrates were made of all samples by the phenol-disulphuric acid method.

THE SEASON OF 1909-'10.

The work started in the summer of 1909. This summer and fall were unusually wet, especially the months of July, September and November. July rainfall amounted to 9.57 inches, September to 5.21 inches, and November to 7.98 inches. The soil was filled almost to its carrying capacity early in the season and remained practically filled with moisture throughout the fall. Table 5 gives the results of the moisture determination for the season of 1909-'10.

TABLE 5. Average percent of moisture to a depth of four feet. Season of 1909-1910.

Plot	Treatment.	July, 1909.	Aug., 1909.	Sept., 1909.	Oct., 1909.	March, 1910.	July, 1910.
1	Disked; not plowed	26 13	19 25	27 27	18.22	19 23	21.40
2	Plowed Sept. 15, 7 in deep	25 53	21 48	25.81	24 82	19 64	21 60
3	Disked July 15; plowed 7 in. deep	26 28	22 44	26.58	23 66	19 79	21 84
4	Disked July 15; plowed Aug. 15, 7 in deep	25 08	22 61	27.76	25 97	19 26	22 41
5	Plowed Sept. 15, 7 in. deep	23.67	20.59	24 91	23.09	19 66	23.42
6	Listed July 15; worked down	25.73	22.82	27 15	25 69	19.15	22 84
7	Listed July 15; ridges split Aug. 15	25 87	22 59	25 95	26 91	19.16	21 93
8	Plowed Sept. 15, 7 in. deep	24 65	20 94	24.78	25 95	19.49	22 50
9	Plowed July 15, 7 in. deep	22 79	23 56	27.16	26 36	19.51	21 48
10	Plowed Aug. 15, 7 in. deep	26 17	19 83	26 26	28.78	19.91	21.59
11	Plowed Sept. 15, 7 in deep	24.14	20 27	25 85	28 55	19 95	22 93
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	23 55	17 63	23 97	27.74	19.32	21.77
13	Plowed Sept. 15, 3 in. deep	24 43	19 49	23.21	25.75	18 81	22.38
14	Plowed Sept. 15, 7 in. deep	23 46	17.89	21.74	24 73	18.76	21.35
15	Plowed July 15, 3 in. deep	23 95	21.85	23 48	24.99	18.72	20.21

The first moisture determinations were made in July, 1909, when the listing, disking and plowing were done on the early-prepared plots. The field had been cropped uniformly to oats the preceding year, and this crop was harvested about two weeks before the moisture determinations were made. The samples were taken two days after a rainy period, in which 5.36 inches of rain fell, so that the soil, especially the surface two feet, was filled to its carrying capacity. There was some

variation in moisture at this time, although the area had been previously uniformly cropped.

The plots that were worked in July prevented weed growth, and the August moisture determinations invariably show more moisture in the worked than in the unworked ground, although there was a loss from all plots. The heavy rainfall during the first part of September again thoroughly saturated the soil, so that when the September determinations were made all ground, regardless of its previous treatment, was filled to its carrying capacity. In October the moisture conditions were practically the same as in September. The only plot showing a marked loss of moisture was the one not plowed and upon which weeds were allowed to grow until seeding time. During the winter there was a loss of moisture from all the plowed and listed plots, so that the moisture in all plots the following spring was practically the same.

The wheat on all the plots winterkilled. There was, however, a scattering growth, which, together with the weeds, was allowed to grow until harvest. The growth was not sufficient to utilize the heavy rainfall of June, and the ground in July contained from 7.41 to 11.26 percent of available moisture.

Nitrate samples were taken in October, 1909, a few days after seeding, and again the following spring. The results are given in table 6.

TABLE 6. Total pounds nitrates in surface three feet of soil. Season 1909-1010.

Plot.	Treatment.	October, 1909.	March, 1910.
1	Disked; not plowed	38.90	32.38
2	Plowed Sept. 15, 7 in. deep	64.26	53.95
3	Disked July 15; plowed Sept. 15, 7 in. deep	84.68	81.23
4	Disked July 15; plowed Aug. 15, 7 in. deep	160.84	81.61
5	Plowed Sept. 15, 7 in. deep	46 85	52 69
6	Listed July 15; worked down	180.49	84 79
7	Listed July 15; ridges split Aug. 15	140 37	78 24
8	Plowed Sept. 15, 7 in. deep	48 45	45.47
9	Plowed July 15, 7 in. deep	193 17	113 41
10	Plowed Aug. 15, 7 in. deep	82 98	69 10
11	Plowed Sept. 15, 7 in. deep	43 96	70 33
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	89 79	62.17
13	Plowed Sept. 15, 3 in. deep	47.51	62.29
14	Plowed Sept. 15, 7 in. deep	42.18	81 08
	Plowed July 15, 3 in. deep	159 69	120 57

The available nitrogen at seeding time was high in all plots plowed early in the summer and thoroughly cultivated. Plot 9, plowed in July seven inches deep, and thoroughly cultivated after plowing, held in the first three feet of soil 193.17 pounds of nitrates, the highest of any plot. The plot listed in July and thoroughly worked after listing ranked second, with 180.49 pounds, while the plots plowed in July three inches deep and the one double disked in July and plowed in August ranked third, with about 160 pounds of nitrates each. Plot 1, disked at seeding and not plowed, contained the least nitrates, 38.90 pounds, while the September-plowed plots ran slightly higher. The August-plowed plots ranked between the July and September plowing. The amount of available nitrogen is, as would be expected, the highest on the ground plowed early and thoroughly cultivated through the summer, and the lowest in the soil which received the least cultivation.

There is a reduction in available nitrogen during the winter in all the plots that contained a large quantity of nitrates the fall before. This loss was not due to leaching, for the samples taken in the spring did not indicate that much nitrogen had been leached from the first into the second and third feet. For instance, in plot 9 the nitrates in the fall and spring were distributed in the three feet of soil as follows:

TABLE 7. Showing the distribution of nitrates in Plot 9 in fall and spring.

	October, 1909.	March, 1910.
First foot	131 10	52.22
Second foot	34 61	31.79
Third foot	27 46	29 40
Total	193 17	113 41

The loss, therefore, appears to have been almost entirely from the surface foot of soil. There is not the increase in the second and third foot that would be expected if the nitrates had been leached. It is possible that the reduction may have been due to denitrification and the nitrogen lost from the soil, but it is more likely that the nitrates were used by organisms in the soil and converted into proteid compounds which could again be broken down for the use of the wheat crop.

The season's results indicate a fairly close correlation between the manner in which the ground was worked and the

plant food liberated as indicated by available nitrogen, but little if any relation existed between the manner of working the ground and the available moisture.

Yields were obtained from none of the plots, on account of severe winter conditions, which caused an almost total loss of the crop. The plots were not harvested separately, because of the manner of killing, which had no relation to the soil treatment. The two-acre area devoted to the work produced in all a little over four bushels of wheat. Weeds made a good growth during the spring and summer, so that the plots were not in any sense summer-fallowed this season.

THE SEASON OF 1910-1911.

The work for the season of 1910-1911 was continued as it had been started the preceding year. Moisture determinations of the soil were made the middle of July when the first preparation work for the season was done, again the middle of August when the August plowing was done, and again the middle of September when the September plowing was done, or about two weeks before seeding. Samples were again taken in March about the time spring growth started, and in July shortly after harvest. The rainfall for the three summer months was unusually heavy, being 5.93 inches for July, 10.70 inches for August, and 2.54 inches for September.

The total available moisture in the surface four feet of soil for the season is shown in table 8.

The moisture content of the different plots in July varied from 20.2 to 23.4 percent. The variation at this time was undoubtedly due to differences in weed growth. The plots that were worked during July (Nos. 3, 4, 6, 7, 9 and 15) all showed slightly more available moisture in August than the adjoining unworked plots, but the heavy rainfall of August nearly saturated all the ground with water, regardless of the manner in which it had been handled. Therefore, at the time of seeding there was but little variation in moisture in the different plots. The condition was the same when growth started the following spring.

At harvest time the available moisture varied from .83 to 2.54 percent. In every instance those plots which had received early and thorough preparation the preceding season were found to be the driest at harvest, and those plots that

TABLE 8. Average percent of moisture to depth of four feet. Season of 1910-1911.

Plot	Treatment.	July, 1910		Aug., 1910.		Sept., 1910.		March, 1911.		July, 1911.	
		Total moisture.	Available moisture.	Total moisture.	Available moisture	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.
1	Disked; not plowed	21 40	8 60	21 24	7 44	25 02	11 22	26 99	13 19	16.26	2 46
2	Plowed Sept. 15, 7 in. deep	21 60	7 87	21 64	7 91	25 27	11 54	27 28	13 55	15 28	1 55
3	Disked July 15; plowed Sept. 15, 7 in. deep	21 84	8.18	23 58	9 02	25 38	11 72	26 29	12 63	14 99	1 33
4	Disked July 15; plowed Aug. 15, 7 in. deep	22 41	8 83	23 58	10 00	26 82	13 23	26 22	12 64	14 87	1.29
5	Plowed Sept. 15, 7 in. deep	23 42	9 91	21 57	8 06	24 37	10 86	25.77	12 26	15.91	2.41
6	Listed July 15; worked down	22 84	9 40	23 38	8 94	24.59	11 15	26 47	13 00	14.27	0 83
7	Listed July 15; ridges split Aug. 15	21.93	8 56	22 58	9.21	25 06	11 09	26 42	13 05	14 47	1.10
8	Plowed Sept. 15, 7 in. deep	22 50	9.20	20.41	7.11	23.98	10 68	26.02	12.72	15 61	2.31
9	Plowed July 15, 7 in. deep	21.48	8.26	22 36	9 14	24.95	11.73	25 52	12.30	14.80	1.58
10	Plowed Aug. 15, 7 in. deep	21 59	8.43	20 66	7.50	25 47	12.31	26.06	12.90	15.16	2.00
11	Plowed Sept. 15, 7 in. deep	22 93	9 85	20.97	7 89	23.94	10.86	25 85	12.77	15.62	2.54
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	21 77	9.76	20 81	7.80	24.77	11.76	25.55	12.54	14 55	1.54
13	Plowed Sept. 15, 3 in. deep	22 38	9 44	20.42	7 48	23.43	10 47	24.73	11.79	15.16	2.22
14	Plowed Sept. 15, 7 in. deep	21.35	8.48	19 69	6.82	23.17	10.30	25 03	12.16	15.19	2 32
15	Plowed July 15, 3 in. deep	20 21	7 41	21 00	8.20	24 05	11 25	26.55	13 75	13.90	1.10

were plowed late and received the poorest preparation contained the most moisture at this time.

The nitrates in the soil were determined in September, and again the following spring in March. The nitrate content of the soil on these dates is shown in table 9.

TABLE 9. Total pounds of nitrates in surface three feet of soil. Season of 1910-1911.

Plot	Treatment.	September.	March.
1	Disked; not plowed	68.60	23.81
2	Plowed Sept. 15, 7 in. deep	77.09	28.20
3	Disked July 15; plowed Sept. 15, 7 in. deep	38 57	28.29
4	Disked July 15; plowed Aug. 15, 7 in. deep	149 72	53 23
5	Plowed Sept. 15, 7 in. deep	53 01	47 64
6	Listed July 15; worked down	158 15	72 18
7	Listed July 15; ridges split Aug. 15	63 34	78 77
8	Plowed Sept. 15, 7 in. deep	39 66	53 77
9	Plowed July 15, 7 in. deep	141.49	112 08
10	Plowed Aug. 15, 7 in. deep	100 75	40 93
11	Plowed Sept. 15, 7 in. deep	38.70	42 78
12	Plowed Sept. 15, 7 in. deep	*89.79	47 65
13	Plowed Sept. 15, 3 in. deep	44 35	28 42
14	Plowed Sept. 15, 7 in. deep	38 10	29 11
15	Plowed July 15, 3 in. deep	88.25	121 56

* Determination lost, figure for preceding season substituted.

The nitrate determinations in September show that the most nitrates occurred in those plots that had been worked throughout the summer. Plot 6, that was listed in July and worked thoroughly after listing, contained the most nitrates, 158.15 pounds per acre to a depth of three feet. Plot 4, double disked July 15 and plowed August 15, came second, with 149.72 pounds, and plot 9, plowed July 15 seven inches deep, contained at this time 141.9 pounds. The only plot that had been worked that showed a lower nitrate content than the adjoining unworked plots was plot 3, which was double disked in July and then left without further work. Upon this plot the weeds made a ranker growth than upon the unworked plots and used for their growth plant food liberated by the early working of the ground. The spring determinations show practically the same reduction in nitrates during the winter that occurred the preceding year. Upon the whole, the nitrate determinations of this season corroborate the results secured in the pre-

ceding season. The largest quantity of nitrate was again found in the ground receiving the earliest and most thorough preparation.

Table 10 gives the yield of grain and straw secured from each plot, the available moisture in percent to a depth of four feet in September shortly before seeding and in July following harvest, and the pounds of nitrates per acre three feet of soil.

TABLE 10. Available moisture in four feet of soil and nitrates in pounds in three feet at seeding time and the yield per acre. Season 1910–1911.

Plot	Treatment.	Percent of available moisture at seeding.	Percent of available moisture at harvest	Total pounds of nitrates at seeding.	Yield per acre.	
					Grain, bushels.	Straw, pounds.
1	Disked; not plowed	11 22	2.46	68.60	6.00	590
2	Plowed, Sept. 15, 7 in. deep	11.54	1.55	77.09	17 50	1,450
3	Disked July 15; plowed Sept. 15, 7 in. deep	11.72	1.33	38 57	25 50	2,120
4	Disked July 15; plowed Aug. 15, 7 in. deep	13.16	1 29	149.72	34.83	3,010
5	Plowed, Sept. 15, 7 in. deep	10.86	2.41	53.01	14 50	1,130
6	Listed July 15; worked down	11 15	0.83	158.15	37.66	3,140
7	Listed July 15; ridges split Aug. 15	11 69	1.10	63 34	37 16	3,070
8	Plowed Sept. 15, 7 in. deep	10 68	2.31	39.66	18.83	1,470
9	Plowed July 15, 7 in. deep	11 73	1 58	141.49	40 00	3,550
10	Plowed Aug. 15, 7 in. deep	12.31	2 00	100.75	28 00	2,320
11	Plowed Sept. 15, 7 in. deep	10 86	2 54	38 70	14 66	1,170
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	11.76	1 54	89 79	21 66	1,800
13	Plowed Sept. 15, 3 in. deep	10.47	2.22	44.35	10 66	940
14	Plowed Sept. 15, 7 in. deep	10.30	2.32	38.10	12 16	1,020
15	Plowed July 15, 3 in. deep	11.25	1.10	88.25	29.83	2,360

The yield of wheat ranged from 6 bushels to the acre on plot 1, where the ground was unplowed, but disked at seeding time, to 40 bushels per acre on plot 9, where the ground was plowed seven inches deep in July. The yield of the other plots fell between these two extremes. Those plots worked the earliest in the summer, and given the best cultivation after working, in every instance made higher yields than those plots worked later in the summer or given poorer treatment.

There seems to be no correlation between the yield of wheat and the moisture in the ground at seeding time. Plot 1, which made the lowest yield, 6 bushels per acre, contained 12.22 percent of available moisture, more than any other plot, while plot 9, which produced 40 bushels per acre, contained 11.73 percent

of available moisture, or .49 percent less than plot 1. There is, however, some relation between the yield of grain and the percent of available moisture left in the ground at harvest. In every instance where a large yield of wheat was secured the ground was found to be comparatively dry at harvest, while every plot which produced a low yield contained a larger amount of available moisture. For example, plot 9, which produced 40 bushels of wheat, left but 1.58 percent of available moisture in the surface four feet of soil, while plot 1, which produced 6 bushels of wheat, left 2.46 percent of available moisture in the soil, and plot .14, which produced but 12.16 bushels of wheat, left 2.32 percent of available moisture. It seems evident that the low yields secured on these low-yielding plots could not have been due to a deficiency of available moisture.

The amount of nitrates in the soil at seeding time is in most instances closely correlated with the yield. In nearly every instance when the ground was worked early in the summer the nitrates were high and the yields were correspondingly high. Plot 9, plowed in July, contained 141.49 pounds of nitrates in the surface three feet of soil at seeding time and produced 40 bushels of wheat. Plot 6, listed in July, contained 158.15 pounds of nitrates and produced 37.66 bushels of wheat, while plot 1, with 68.50 pounds of nitrates, produced but 6 bushels, and plot 14, with 38.1 pounds of nitrates, produced but 12.16 bushels. On plots 3 and 7 comparatively high yields were obtained on ground that contained relatively small amounts of nitrates at seeding. Plot 3 was double disked in July and was not plowed until the middle of September. The weed growth was very rank upon this plot, and undoubtedly used nitrates that were liberated by the early disking. It is possible that these green weeds decayed rapidly the next spring and the nitrogen stored in their tissues became available for the wheat crop. It is impossible to account for the small amount of nitrates found in plot 7, but it will be observed from table 9 that the nitrate content of this plot was slightly higher than that of plot 6 when growth started the following spring. Upon the whole, there seems to be a close correlation between the amount of plant food liberated in the preparation of the ground for the crop as indicated by the nitrates and the yield of wheat obtained.

THE SEASON OF 1911-1912.

The season of 1911-1912 was very unfavorable for winter wheat, although the conditions were favorable in the summer and fall for the preparation of the ground. The wheat made a good growth and went into the winter in good condition. However, the heavy rains and snows that fell during the last of February and March left the ground very hard and compact, and this crusted condition undoubtedly resulted in poorer aëration. The wheat, during the spring and early summer, appeared to be suffering for moisture, although the moisture determinations taken at the time showed sufficient available moisture to have produced satisfactory growth in a normal season. The season opened late in the spring and the growth of the wheat was backward, which may have been partly responsible for the poor crop.

Moisture determinations were made at about the same intervals as in the preceding year. Table 11 gives the average percent of total and available moisture to a depth of four feet for each plot at each date of sampling.

In July, 1911, the amount of available moisture in the soil varied from .83 to 2.46 percent. The soil was drier on those plots that had produced a large yield the season before than it was where the yield the preceding season had been light. Rain to the amount of 4.23 inches fell during the latter part of July and the first of August. The moisture determinations in August, therefore, showed more moisture in every plot than was present in July. The increase in moisture was nearly, if not quite, as great in the uncultivated as in the cultivated plots. Between the time the moisture was determined in August and in September 2.15 inches of rain fell. Weeds had made a good growth by the latter date on all uncultivated plots, so that there was but little gain and in some instances a loss of moisture from these plots during this period. The cultivated plots all show an increase in moisture. Heavy rains fell between the September and October dates of sampling, the total rainfall amounting to 4.56 inches. These rains stored additional moisture in the soil, so that at seeding time, on October 4, the ground on every plot, regardless of the method of treatment, was well supplied with moisture. At the beginning of growth in the spring (April) the soil was nearly saturated with moisture, the amount of available mois-

TABLE 11. Average percent of moisture to depth of four feet. Season 1911-1912.

Plot.	Treatment.	July, 1911.		Aug., 1911.		Sept., 1911.		Oct., 1911.		April, 1912.		July, 1912.	
		Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.
1	Double disked; not plowed	16.26	2.46	18.39	4.59	18.73	4.93	21.69	7.89	22.71	8.91	19.6	5.80
2	Plowed Sept. 15, 3 in. deep	15.28	1 55	18 28	4.55	17.49	3.76	21.09	7.36	20.88	7.15	17.9	4.17
3	Double disked July 15; plowed Sept. 15, 3 in. deep	14.99	1 33	16 93	3 27	16.67	3.01	21.06	7.40	20.25	6 59	17.3	3.64
4	Double disked July 15; plowed Aug. 15, 3 in. deep	14.87	1.29	17.01	3.43	19.68	6.10	21.35	7.77	20.99	7.41	17.8	4.22
5	Plowed Sept. 15, 3 in. deep	15.91	2.41	18.01	4.50	17.76	4.25	21.58	8.07	23.68	10.17	19.2	5 69
6	Single listed, July 15	14.27	0.83	16.66	3.22	18 59	5.15	22.08	8.64	19.66	6.22	18.2	4.76
7	Listed July 15; ridges split Aug. 15	14.47	1.10	17.38	4.01	18.05	4.68	21.06	7.69	20.07	6.70	16.7	3.33
8	Plowed Sept. 15, 3 in. deep	15 61	2.31	16 88	3.58	16.40	3.19	20.49	7.10	22.36	9.06	17.5	4.20
9	Plowed July 15, 7 in. deep	14.80	1 58	17.16	3.94	18.35	5.12	20.22	7.00	20.26	7.04	17.8	4 58
10	Plowed Aug. 15, 7 in. deep	15.16	2 00	18 07	4 91	19 26	6.10	22.62	9 46	22.65	9 49	17.8	4.64
11	Plowed Sept. 15, 3 in. deep	15 62	2 54	17 09	4 01	16 79	3 71	20 38	7.30	22.29	9 21	19 3	6.22
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	14 55	1 54	16 69	3 68	18 61	5 60	22 11	9 10	23 03	10 02	18 3	5 29
13	Plowed Sept. 15, 7 in. deep	15 16	2 22	17 33	4 39	16 75	3 81	21 08	8 14	22 99	10 05	19 7	6 76
14	Plowed Sept. 15, 3 in. deep	15 19	2 32	16 18	3 31	15 72	2 85	20 07	7 21	23 03	10.16	18 2	5 33
15	Plowed July 15, 3 in. deep	13 90	1 10	15 49	2 69	18 43	5 63	19 61	6 81	21 40	8 60	16 9	6 80

ture varying from 6.22 to 10.17 percent at this time. Those plots that were plowed late in the summer contained the most moisture. They were looser and absorbed the winter rains more readily. At harvest all plots contained an abundance of available moisture, indicating that the ground in all cases contained more moisture than was required by the wheat.

Nitrate determinations were made each month that moisture samples were taken. Table 12 gives the total pounds of nitrates found per acre in the upper three feet of soil.

TABLE 12. Total pounds of nitrates in surface three feet of soil. Season of 1911-1912.

Plot	Treatment.	July.	August.	Sept.	October.	April.	July, '12.
1	Double disked; not plowed	49.67	73.28	34.39	22.49	60.52	56.18
2	Plowed Sept. 15, 3 in. deep	58.64	131 28	46.00	95.69	103.28	116.53
3	Double disked July 15; plowed Sept. 15, 3 in. deep	69.23	179.92	38.36	81.67	106.21	173.04
4	Double disked July 15; plowed Aug. 15, 3 in. deep	75.58	157.53	200.72	295.96	226.89	278.08
5	Plowed Sept. 15, 3 in. deep	72.19	148.87	56.56	96.37	111.99	124.63
6	Single listed July 15	63.87	158.23	191.77	247.10	246.70	195.04
7	Listed July 15; ridges split Aug. 15	43.18	149.64	140.53	251.45	191.86	178.41
8	Plowed Sept. 15, 3 in. deep	56.78	114.50	40.52	105.21	68.75	103.65
9	Plowed July 15, 7 in. deep	51.22	221.55	223.18	386.58	305.22	154.43
10	Plowed Aug. 15, 7 in. deep	50.61	151.32	160.03	250.29	266.79	112.39
11	Plowed Sept. 15, 3 in. deep	33.73	144.00	29.53	57.66	80.30	124.91
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	35.26	91.42	207.43	202.22	119.04	124.43
13	Plowed Sept. 15, 7 in. deep	39.21	67 27	20 75	42.95	43.52	87.62
14	Plowed Sept. 15, 3 in. deep	39.27	95.34	24.64	64.79	47.89	94.79
15	Plowed July 15, 3 in. deep	44 67	159.83	177.46	282.44	362.05	170.65

This table shows that in July, 1911, the plots contained but a small quantity of nitrates, varying in amount from a little over 33 pounds per acre three feet to a little less than 76 pounds. During the next month there was a gain in nitrates in all plots. The greatest gain, however, occurred in the plots that were cultivated during this period. Plot 9, that was plowed July 15 and cultivated, increased in nitrates from 51.22 pounds to 221.55 pounds per acre three feet. Between the middle of August and the middle of September all plots that had not been cultivated decreased in nitrates, due to grass and weeds that grew rapidly during this period. All the cultivated plots increased in nitrates except plot 7, which

showed a slight decrease. All plots increased in nitrates during the next month with the exception of plots 12 and 1. Plot 12 remained practically constant, while plot 1, which was not plowed but disked at seeding time, decreased nearly 30 percent.

During the winter there was a slight decrease in nitrates in nearly all plots that contained a large quantity in the fall, but this loss was not nearly so great as in the two preceding winters, although the winter of 1911-'12 was much milder and there was more leaching than during either of the other years. A large quantity of nitrates still remained in the soil at harvest time. The crop did not reduce the supply nearly so completely as it did the season before. It is evident that the yield of wheat could not have been limited by a lack of available nitrogen this season.

Table 13 gives the yield of grain and straw secured from each plot in 1912, the available moisture, in percent, to a depth of four feet in October shortly after seeding, and in July after harvest, and the pounds of nitrates per acre three feet of soil in October after seeding.

TABLE 13. Available moisture in four feet of soil and pounds of nitrates in three feet of soil at seeding time, and yield per acre. Season of 1911-1912.

Plot.	Treatment.	Average percent of available moisture in four feet.		Total pounds of nitrates in 3 feet, October 9.	Yield per acre.	
		Seeding.	Harvest.		Grain.	Straw.
					Bushels.	*Pounds.*
1	Double disked; not plowed	8.69	6 60	22.49	4 17	410
2	Plowed Sept. 15, 3 in. deep	7.36	4 17	95 69	6 83	950
3	Double disked July 15; plowed Sept. 15, 3 in. deep	7.42	3.64	81.67	6 33	880
4	Double disked July 15; plowed Aug. 15, 3 in. deep	7.77	4 22	205 96	6.33	1,120
5	Plowed Sept. 15, 3 in. deep	8.08	5.69	96 37	7.83	900
6	Single listed July 15	8.64	4.76	247.10	5 33	895
7	Listed July 15; ridges split Aug. 15	7.69	3.43	251 45	5 75	1,055
8	Plowed Sept. 15, 3 in. deep	7.19	4 00	105 21	10 58	1,035
9	Plowed July 15, 7 in. deep	7 23	4 58	386 58	9 75	1,250
10	Plowed Aug. 15, 7 in. deep	9 46	4.34	250 29	14 33	1,540
11	Plowed Sept. 15, 3 in. deep	7.30	6 22	57 66	10.66	895
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	9 10	5 29	202 22	10.08	1,185
13	Plowed Sept. 15, 7 in. deep	8 14	6.76	42.95	9 42	845
14	Plowed Sept. 15, 3 in. deep	7.21	5.33	64.79	8 42	805
15	Plowed July 15, 3 in. deep	7.81	6 80	282 44	6 83	880

It will be seen from the preceding table that the yields of grain varied from 14.33 bushels per acre on plot 10, which was plowed August 15, to 4.17 bushels per acre on plot 1, which was simply disked at planting time. The production of wheat appears not to be correlated with either the moisture or nitrates present in the soil at seeding time. Some other condition must have been the limiting factor, undoubtedly the poor physical condition of the soil in the spring and the unfavorable weather during April.

THE SEASON OF 1912-'13.

The fall of 1912 and the summer of 1913 were abnormally dry, yet the season, upon the whole, was a favorable one for winter wheat. During the months of July, August and September, 1912, there was sufficient moisture to keep the ground in good condition for cultivation, so that it was possible to prepare a good seedbed for the crop, regardless of the time at which the plowing was done. The work was conducted this season as it had been for the past three seasons. Table 14 gives the moisture data secured for the year.

After the crop was harvested in 1912 the average percent of moisture remaining in the soil to a depth of four feet varied from 16.7 to 19.6 percent. There was sufficient moisture in the ground in the middle of July so that the ground worked well on all plots. There was a loss of moisture between July and August on nearly all plots. The plots that were worked during this period retained, on the whole, no more moisture than the unworked plots. Although the soil was drier when the August plowing was done than it was in July, it still contained sufficient moisture to plow and work down fairly well. The moisture increased in all plots between August and September, but remained nearly constant between September and October. The moisture conditions at seeding time, as represented by the sample taken in October, were much the same upon all plots, regardless of the method of preparation. The plots plowed in August contain slightly more available moisture at this time than any other plots, although plot 1, which was disked at planting and not plowed, contains nearly as much. On the whole, the September-plowed plots contained as much available moisture as those plots plowed or listed two months earlier.

TABLE 14. Average percent of moisture to depth of four feet. Season of 1912-1913.

Plot.	Treatment.	July, 1912.		Aug., 1912.		Sept., 1912.		Oct., 1912.		March, 1913.		July, 1913.	
		Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.	Total moisture.	Available moisture.
1	Disked at planting; not plowed	19.6	5.80	18.20	4.40	19.39	5.50	20.57	6 77	22.56	8.76	18.80	5.00
2	Plowed Sept. 15, 3 in. deep	17.9	4.17	17.18	3.44	18.60	4.87	19.56	5.83	22.44	8.71	15.30	1.57
3	Double disked July 15; plowed Sept. 15, 7 in. deep	17.3	3.64	17.20	3.63	18.78	5.12	20.21	6.55	21.58	7.92	14.20	0.54
4	Double disked July 14; plowed Aug. 15, 7 in. deep	17.8	4.22	17.89	4.31	20.06	7.38	20.65	7.99	21.76	8.18	14.58	1.00
5	Plowed Sept. 15, 3 in. deep	19.2	5.69	17.79	4.28	19.20	5.69	19.11	5.60	22.86	9.35	15.80	2.29
6	Single listed July 15	18.2	4.76	18.04	4.60	19.29	5.85	18.63	5.19	21.08	7.64	15.72	2.28
7	Listed July 15; ridges split Aug. 15	16.7	3 33	17.03	3.66	19.01	5.54	17.85	4.48	21.18	7.71	14.76	1.30
8	Plowed Sept. 15, 3 in. deep	17.5	4.20	16.94	3.64	17.39	4.09	17 98	4.68	19.57	6.27	15.49	2.19
9	Plowed July 15, 7 in. deep	17.8	4.58	16.81	3.59	18.95	5.73	18.02	4.80	19.62	6.40	13.90	0.68
10	Plowed Aug. 15, 7 in. deep	17.8	4.64	16 01	2.85	19.35	6.19	19.71	6.55	19.70	6 54	15 52	2.36
11	Plowed Sept. 15, 3 in. deep	19 3	6.22	15.93	2.85	17.58	4 50	18.26	5 18	20.66	7 58	15 19	2.11
12	Plowed Aug. 15, 7 in. deep	18.3	5.29	16.58	3 57	20 52	7 51	19.79	6 78	21.22	8 21	14 81	1 80
13	Plowed Sept. 15, 7 in. deep	19.7	6.76	16 70	3.76	18 35	5 41	19 21	6 27	21.83	8 89	15 02	2 08
14	Plowed Sept. 15, 3 in. deep	18.2	5 33	15.61	2.74	18.32	5.45	17.84	4 97	20.13	7 26	15.17	2 30
15	Plowed July 15, 3 in. deep	16.9	6 80	17 74	4.04	19 18	6.38	18.72	5.92	20 22	7 42	14 84	2 01

The rainfall during the winter was comparatively light. However, the moisture came principally in the form of rain that fell on unfrozen ground and was absorbed, so that there was considerable increase in moisture in nearly every plot. At harvest those plots which had been prepared well and had produced the heaviest crop of wheat contained the least moisture. However, in no instance was the moisture reduced below the wilting coefficient. The plots poorly prepared, which consequently produced a light growth of wheat, contained the most available moisture at harvest.

The quantity of nitrates in the soil was determined at the same time moisture determinations were made. Table 15 gives the results of these determinations.

TABLE 15. Total pounds of nitrates in surface three feet of soil. Season of 1912-1913.

Plot	Treatment.	July.	August.	September.	October.	March.
1	Disked at planting; not plowed	56 18	27 35	9 33	22.43	24.87
2	Plowed Sept. 15, 3 in. deep	116 53	34.68	34.87	76 15	39.51
3	Double disked July 15; plowed Sept. 15, 7 in. deep	173 04	177 27	255 52	263.16	128.79
4	Double disked July 15; plowed Aug. 15, 7 in. deep	278.08	185 02	477.96	384.70	191 62
5	Plowed Sept. 15, 3 in. deep	124 63	11.64	23 88	73.66	28.41
6	Single listed July 15	195 04	247 67	485 73	372.15	221.48
7	Listed July 15, ridges split Aug. 15	178 41	185.26	565.58	522.06	141.36
8	Plowed Sept. 15, 3 in. deep	103 65	24.28	61 23	77.71	23.16
9	Plowed July 15, 7 in. deep	154.43	307.61	428.94	407.94	152 91
10	Plowed Aug. 15, 7 in. deep	112.39	55.66	255.92	255.76	80.54
11	Plowed Sept. 15, 3 in. deep	124 91	48 28	76 55	52 38	27.22
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15	124 43	69 81	233.52	243.20	88.02
13	Plowed Sept. 15, 7 in. deep	87.62	18 81	37.73	76.83	24.53
14	Plowed Sept. 15, 3 in. deep	94.79	11.79	45 28	57 30	23.93
15	Plowed July 15, 3 in. deep	170 65	248 32	366 55	517 07	109 82

The amount of nitrates in the soil increased gradually from July to September on all plots where the preparation of the seed bed was started in July and the ground worked as needed. After September there was in most plots no increase in nitrates, and in some plots a slight loss. The plots that were not worked until August or September show a reduction in nitrate content as the weeds began to grow. At seeding time, as shown by the determinations of October, the quantity of

nitrates in an acre three feet of soil varied from 22.43 pounds on the unplowed plot to 522.06 pounds on the plot listed in July and the ridges split in August. The average nitrate content of all plots plowed or listed in July was 454.80 pounds per acre three feet; for all plots plowed in August, 294.55 pounds; for all plots plowed in September, excepting the plot double disked in July, 69 pounds; and the plot not plowed at all, but simply disked at planting time, 22.43 pounds.

The same reduction in the quantity of nitrates occurred during the winter of 1912-1913 that has been observed in previous years.

Table 16 gives the yield of grain and straw secured from each plot in 1913, the available moisture in the surface four feet of soil at seeding and in the summer after harvest, and the pounds of nitrates in the surface three feet of soil at seding.

The variation in the amount of moisture in the soil at seeding time had little if any effect upon the yield of wheat. Plots

TABLE 16. Available moisture in four feet of soil at seeding and harvest and pounds of nitrates in three feet of soil at seeding time, and yield per acre. Season of 1912-1913.

Plot.....	Treatment.	Average per cent of available moisture in 4 feet.				Total pounds of nitrates in 3 feet, October 9.	Yield per acre.	
		Seeding.		Harvest.				
		Total.	Available.	Total.	Available.		Grain, bushels.	Straw, pounds.
1	Double disked; not plowed.....	20.57	6.77	18.80	5 00	22.43	13 00	1,205
2	Plowed Sept. 15, 3 in. deep.....	19.56	5.83	15.30	1.57	76.15	20 00	1,840
3	Double disked July 15; plowed Sept. 15, 3 in. deep.....	20.21	6.55	14.20	0.54	263 16	29 91	3,105
4	Double disked July 15; plowed Aug. 15, 3 in. deep.....	20.65	7.99	14.58	1.00	384.70	31 00	3,480
5	Plowed Sept. 15, 3 in. deep	19.11	5.60	15.80	2.29	73 66	16.33	1,560
6	Single listed July 15.....	18.63	5.19	15.72	2.38	372 15	28.58	2,945
7	Listed July 15; ridges split Aug. 15..	17.85	4.48	14.76	1.39	522.06	31 00	3,410
8	Plowed Sept. 15, 3 in. deep.	17.98	4.68	15.49	2.19	77.71	18.83	1,470
9	Plowed July 15, 7 in. deep.....	18.02	4.80	13.90	0.68	407.94	36.00	4,170
10	Plowed Aug. 15, 7 in. deep.	19.71	6.55	15 52	2.36	255.76	32.50	3,250
11	Plowed Sept. 15, 3 in. deep.....	18.26	5.18	15 19	2 11	52 38	14.66	1,230
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15....	19.79	6.78	14.81	1 80	243 20	26.47	2,870
13	Plowed Sept. 15, 7 in. deep.	19.21	6.27	15.02	2 08	76.83	14 17	1,130
14	Plowed Sept. 15, 3 in. deep	17.84	4.97	15.17	2.30	57.30	12 50	1,090
15	Plowed July 15, 3 in. deep	18 72	5 92	14 84	2 04	517 07	17 33	2,040

7 and 9 contained as little available moisture as any of the plots, yet these were two of the highest-yielding plots. Plot 9 produced 36 bushels per acre and plot 7 yielded 31 bushels. On the other hand, the plots that made a low yield in nearly every instance contained a relatively large amount of moisture at seeding. It will be seen that at harvest the plots which produced high yields used nearly if not quite all of the available moisture in the soil, while the low-yielding plots left from one and one-half to five percent of available moisture. Apparently, the low yield was not the result of a deficient supply of moisture. Plot 1, which produced but 13 bushels of wheat per acre, the lowest yield of any plot, had 5 percent of available moisture still left in the soil at harvest.

When the yield of wheat is compared with the nitrates in the soil at seeding it will be seen that they are very closely correlated. In every instance where a large amount of nitrates is found the yield is high, and where the nitrates are low the yield is low. One exception to this is plot 15. The low yield secured in this instance can not be explained. This plot has been plowed shallow from the time the work was started, and undoubtedly for many years before, and this, together with a rather more severe chinch-bug injury upon the plot, may have been responsible for the low yield.

The close relation that exists between the supply of nitrates in the soil at seeding and the yield would indicate that the supply of available nitrogen was the factor limiting yield, although the supply of available phosphorus and potassium was undoubtedly high where the nitrates were high. Early plowing and good, thorough preparation of the soil not only liberates nitrogen, but the mineral elements of plant food as well. That nitrogen was the limiting element of plant food on the ground that was poorly prepared for wheat, and that sufficient nitrogen was available on well-prepared ground, is well shown from results secured this season on the fertility plots at this station. Fertilizers were applied on ground where wheat has been grown continuously for eight years and where the seedbed was prepared in the best possible manner by deep July plowing. While the nitrates were not determined in this ground, they were undoubtedly high. The results secured from fertilizer upon this ground is shown in table 17.

TABLE 17. Effect of fertilizers upon yield of wheat on July plowed ground. Season of 1913.

Treatment.	Yield grain per acre, bushels.	Percent increase due to fertilizer.
None	17.64	.....
Phosphorus and potassium	19.34	9.64
Phosphorus and nitrogen	18.56	5 22
Potassium and nitrogen	15.38	—12 81
Potassium, phosphorus and nitrogen	16.39	—7 09

Nitrogen gave no increase in the yield of wheat on July-plowed ground; in fact, there was a slight decrease in yield. The large quantity of nitrates liberated in the preparation of the seedbed supplied the plant with all the nitrogen needed for growth.

Fertilizers were also used on ground which grew corn the previous year. A seedbed was prepared for the wheat by double disking the ground after the corn crop was removed. Table 18 gives the results of this work.

TABLE 18. Effect of fertilizer on yield of wheat on disked corn ground. Season of 1913.

Treatment.	Yield grain per acre, bushels.	Percent increase due to fertilizer.
None	11 43	.....
Phosphorus and potassium	14.19	24.14
Phosphorus, potassium and nitrogen	25 20	120 47

On the ground where corn was grown the previous season and where there was no opportunity to work the soil and liberate nitrates, an application of nitrogen in the form of nitrate of soda gave an increase of nearly 100 percent. It appears, therefore, that on late-plowed ground or on ground otherwise worked late, nitrogen was not liberated in sufficient quantities to supply the crop with the amount of this plant food necessary for the maximum growth. Under such conditions a lack of nitrogen was responsible for the low yields. On the other hand, where the ground was prepared early in the season sufficient nitrogen was liberated, and nitrogenous fertilizers when supplied did not increase the yield.

It appears, therefore, that early plowing in preparing land for wheat under state conditions is of value because of the

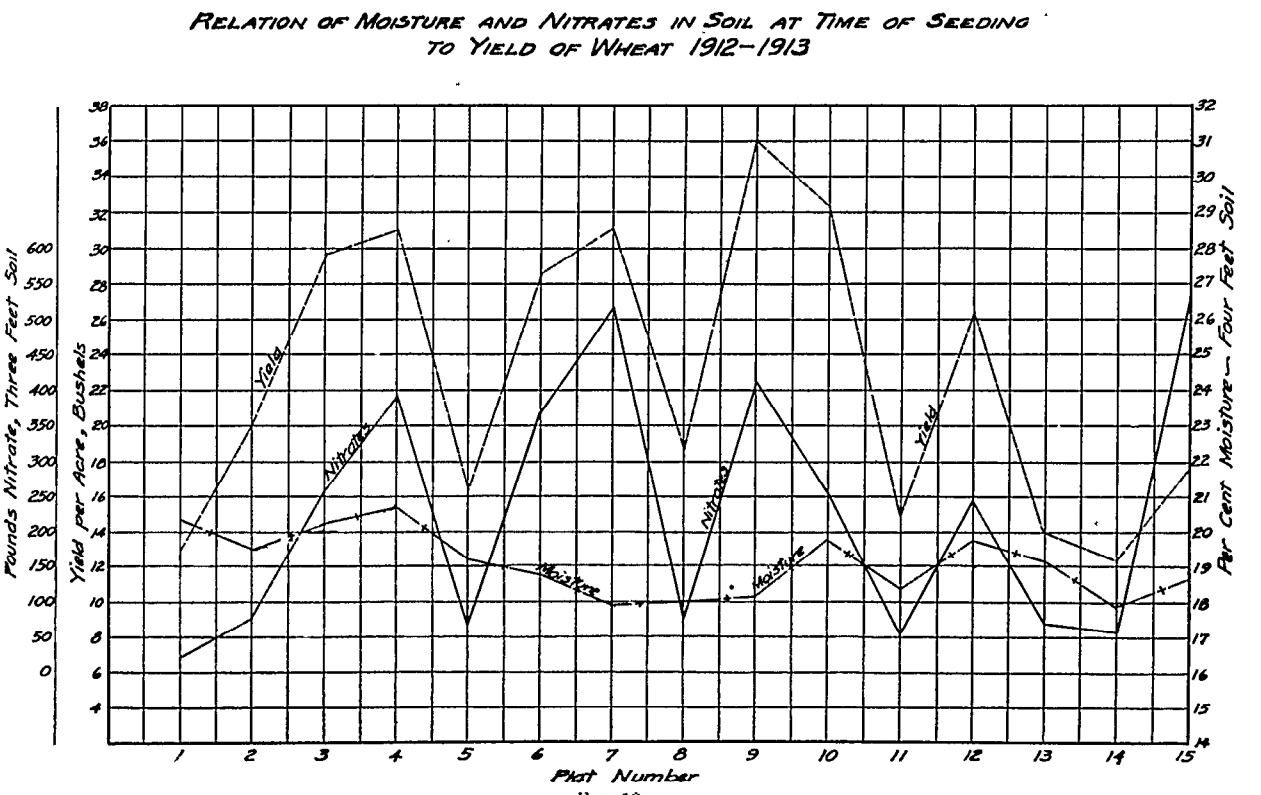

FIG. 13.

large supply of plant food liberated, especially nitrates, rather than for any additional moisture that is stored in the soil by the early cultivation; and that poor results are secured from late plowing chiefly because plant food is not liberated in sufficient quantities to supply the needs of the crop.

AVERAGE OF THREE YEARS' RESULTS.

The table which follows, No. 19, gives the yield of wheat for each of the different methods of preparation used in preparing the seedbed for wheat for the seasons of 1911, 1912 and 1913, and the average for these years.

TABLE 19. Yield of wheat for each of the different methods of preparation used for the seasons of 1911, 1912, and 1913, and the average yield for the three years.

Plot.	Treatment.	Yield per acre.							
		1911.		1912.		1913		Average.	
		Grain, bu.	Straw, lbs.	Grain, bu.	Straw, lbs.	Grain, bu.	Straw, lbs.	Grain, bu.	Straw, lbs.
1	Double disked; not plowed.	6.00	590	4.17	410	13.00	1,205	7.72	738
2	Plowed Sept. 15, 3 in. deep.	17.50	1,450	6.83	950	20 00	1,840	14.77	1,413
3	Double disked July 15; plowed Sept. 15, 3 in. deep	25 00	2,120	6 33	880	29 91	3,105	20 41	2,035
4	Double disked July 15; plowed Aug. 15, 3 in. deep,	34.83	3,010	6 33	1,120	31 00	3,480	24 05	2,537
	Plowed Sept. 15, 3 in. deep.	14 50	1,130	7 83	960	16 33	1,560	12 88	1,197
6	Single listed July 15.....	37 66	3,140	5.33	895	28 58	2,945	23 86	2,327
7	Listed July 15; ridges split Aug. 15.....	37.16	3,070	5.75	1,055	31 00	3,410	24 64	2,512
8	Plowed Sept. 15, 3 in. deep	18.83	1,470	10.58	1,035	18 83	1,470	16 08	1,325
9	Plowed July 15, 7 in. deep..	40.00	3,550	9 75	1.250	36 00	4,170	28 58	2,990
10	Plowed Aug. 15, 7 in. deep.	28 00	2,320	14 33	1,540	32 50	3,250	24 94	2,370
11	Plowed Sept. 15, 3 in. deep.	14 66	1,170	10 66	895	14 66	1,230	13 33	1,098
12	Plowed Aug. 15, 7 in. deep; not worked until Sept. 15,	21.66	1,800	10 08	1,185	20 47	2,870	17 40	1,952
13	Plowed Sept. 15, 7 in. deep.	10.66	940	9 42	845	14 17	1,130	11.42	972
14	Plowed Sept. 15, 3 in. deep.	12.16	1,020	8 42	805	12 50	1,090	11 03	972
15	Plowed July 15, 3 in. deep..	29 83	2,360	5 83	880	17 33	2,040	17 66	1,760

The largest acre yield, 28.58 bushels of grain and 2990 pounds of straw, was obtained from the ground plowed seven inches deep in July. Ground plowed the same date but only three inches deep produced an average yield of but 17.66 bushels of wheat and 1700 pounds of straw per acre—a difference in yield of grain of 10.92 bushels. A part of this differ-

ence in yield is accounted for by the variation in soil, as indicated by the check plots. The ground that was plowed shallow was on the poorer soil.

Ground plowed seven inches deep in August produced an average of 24.94 bushels of grain and 2370 pounds of straw. Ground plowed the same date and the same depth, but left without work for one month, produced but 17.40 bushels of grain and 1952 pounds of straw. Plot 13, plowed one month later, but otherwise worked at the same time and given the same amount of work as plot 12, produced but 11.42 bushels of grain and 972 pounds of straw. These results demonstrate the value of working plowed ground early; but they also show the importance of early plowing, even though it is impossible to work the ground as quickly as necessary after the plowing is done.

Ground plowed shallow (three inches deep) in September varied in yield from 11.03 bushels to 16.08 bushels per acre on

FIG. 14. The grain produced on five plots in 1913.

the five different check plots, the average being 13.62 bushels of grain and 1201 pounds of straw per acre. This is 11.32 bushels less wheat than was produced on August-plowed ground and 14.96 bushels less wheat than was produced on July-plowed ground.

Ground that has been single listed each season in July pro-

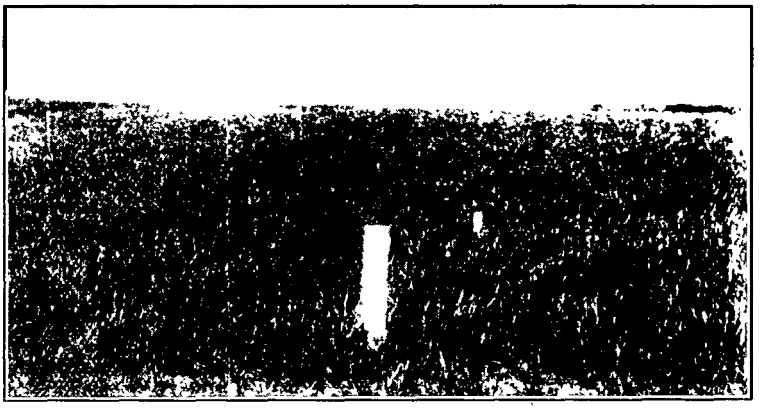

FIG. 15. Plot 9. Growth of wheat April 29, 1911. Plowed July 15, seven inches deep. Note the small white stake in the foreground. This stake occupies the same relative position in each picture.

duced an average yield of 23.86 bushels of grain and 2327 pounds of straw, while ground that has been double listed (listed in July and the ridges split in August) produced an average yield of 24.64 bushels of grain and 2512 pounds of straw. Neither method has produced as much wheat or straw as deep plowing done at the same time as the listing. In fact, ground plowed in August has exceeded the July-listed ground in yield.

Double disking in July, ground that was to be plowed in September, has greatly increased the yield over undisked ground plowed on the same day. Plot 3, double disked each

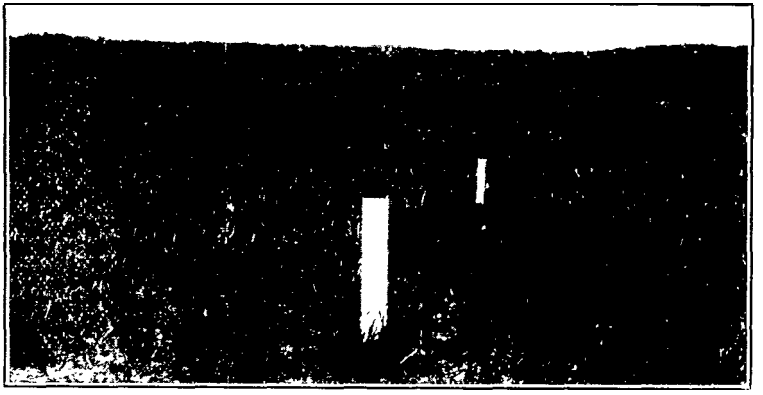

FIG. 16. Plot 8. Growth of wheat April 29, 1911. Plowed September 15, seven inches deep.

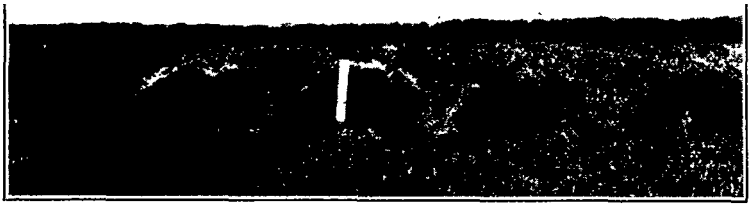

FIG. 17. Plot 10. plowed August 15, seven inches deep. Harvest of 1911, yield per acre: Grain, 28 bushels; straw, 2320 pounds.

season in July and plowed in September, produced an average yield of 20.41 bushels of grain and 2035 pounds of straw, while the adjoining check plot, plowed the same depth, the same day, but not double disked, produced but 14.77 bushels of grain and 1403 pounds of straw. This is a difference of 5.64 bushels of grain and 622 pounds of straw per acre in favor of the ground double disked two months before plowing. Ground double disked in July and plowed in August produced slightly less wheat as an average of the three years than ground plowed the same date but not previously disked. The disked ground, however, produced slightly more straw.

The smallest yield was obtained from the ground that had not been plowed, but disked each season at the time of planting to secure enough loose dirt to cover the seed. This plot has produced but 7.72 bushels of grain and 735 pounds of straw per acre as an average of the three years. This yield is but approximately one-half that secured from ground plowed three inches deep in September, and but one-fourth as much as that secured from ground plowed seven inches deep in July.

FIG. 18. Plot 12. Plowed August 15, seven inches deep, but left without working until September 15. Harvest of 1913, yield per acre: Grain, 21.66 bushels; straw, 1800 pounds.

SUMMARY.

Ground cropped continuously to winter wheat and plowed each season July 15 seven inches, and thoroughly worked after plowing, produced, as an average of three years, a yield of 28.58 bushels of grain per acre; ground plowed August 15 produced 24.94 bushels per acre, while ground plowed September 15 produced but 13.62 bushels per acre.

Ground plowed three inches deep in July produced as an average of three years 10.92 bushels less wheat than ground plowed seven inches deep the same date.

Both single and double listing have given smaller yields of wheat than deep plowing.

FIG. 19. Plot 9. Plowed July 15, Seven inches deep. Harvest of 1911, yield per acre: Gram, 40 bushels; straw, 3550 pounds.

Early disking was advantageous when the plowing was delayed until September, but did not increase the yield when the plowing was done in August.

Early working of the ground, regardless of method, has usually produced an increased yield, and late working, regardless of method, has usually given a reduced yield.

There was practically no relation between the amount of water in the soil at seeding time and the yield of wheat secured. In some seasons the ground that contained the most moisture at seeding produced the smallest yield of wheat.

The amount of moisture in the soil at seeding time was influenced more by the size of the crop produced the preceding season than by the method of preparing the ground for that season's crop.

Early plowing and thorough working of the soil liberated large quantities of nitrates.

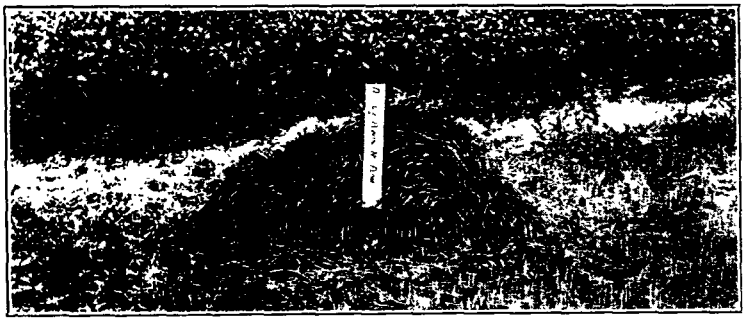

FIG. 20 Plot 1. Ground not plowed. Seed bed prepared by disking at time of seeding, Harvest of 1911, yield per acre: Grain, 6 bushels; straw, 590 pounds.

There was a close correlation in both 1911 and 1913 between the amount of nitrates in the soil at seeding time and the yield of wheat. While the yield of wheat was not in direct proportion to the amount of nitrates present in the soil, yet large yields were only obtained when nitrates were present in large quantities, and small yields were usually obtained when nitrates were low.

Moisture was more completely used by the wheat in those plots that contained a large supply of nitrates at seeding time. There is considerable evidence to show that moisture was more economically used in those plots that contained a large supply of nitrates.

Nitrogenous fertilizers did not increase the yield of wheat on ground plowed in July and which was rich in nitrates, while on disked corn ground a nitrogenous fertilizer increased the yield of wheat nearly 100 percent.

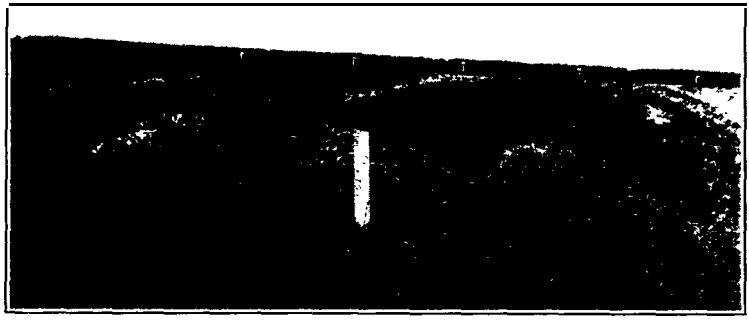

FIG. 21. Plot 2. plowed September 15, seven inches deep. Harvest of 1911, yield per acre: Grain, 17.5 bushels; straw, 1450 pounds.

It appears that early plowing in preparing land for winter wheat is of value principally because of the large supply of plant food liberated, especially nitrates, rather than from any other cause; and that poor results are secured from late plowing chiefly because plant food is not liberated in sufficient quantities to supply the needs of the crop.

ACKNOWLEDGMENTS.

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