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A Report of Progress in Soil Fertility Investigations

J.G. Hutton

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SOUTH DAKOTA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

AGRONOMY DEPARTMENT

A Report of Progress in Soil Fertility Investigations

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BROOKINGS, SOUTH DAKOTA

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SUMMARY OF BULLETIN

1. The average value of the crops produced at Brookings for five years was 31.1 per cent greater where phosphorus alone was applied than where no phosphorus was applied ....Page 256

2. The average value of the crops produced at Brookings for five years was *greater where phosphorus alone was applied than where any other element of plant food was applied or where any combination of elements of plant food was applied*........................Page 255

3. If the fact that more than one half of the phosphorus applied yet remains in the soil is taken into consideration, the application of phosphorus even in an expensive form seems to be commercially profitable...Page 258

4. Phosphorus is the limiting element of plant food in crop production in the soil at Brookings.....Page 250

5. It does not pay to buy nitrogen........Page 257

6. Grow legumes to add nitrogen to the soil Page 251

7. It does not pay to buy potassium.......Page 257

8. The application of plant food cannot take the place of rainfall ....Page 260

Note.—If plant food can be applied to some soils at a profit to the farmer and to other soils at a loss, a soil and crop survey to enable the state to ascertain the facts will add millions of dollars to the state's wealth and point the way to permanent, profitable agriculture.

Rainfall data on page 263.

A Report of Progress in Soil Fertility Investigations

Joseph Gladden Hutton

INTRODUCTION

The object of this bulletin is to report the progress of the soil fertility investigations which are being conducted by the Agronomy Department of the South Dakota Agricutural Experiment Station.

The work was begun while Mr. C. Willis was the Station agronomist, 1908-1910. After Mr. Willis' resignation in November, 1910, the work was carried on by assistants until June, 1911, when Dr. A. N. Hume assumed the duties of Agronomist. Since then, the writer has had charge of the details of the work under the immediate direction of Dr. Hume. Field tests have been directed largely by the writer also in part of Mr. C. Woodworth, formerly Assistant in Crops and later by Mr. Manley Champlin.

PURPOSE OF THE WORK

The investigations in the field of soil fertility are concerned with the amount of plant food in the soil and its relation to crop yields. Answers to the following questions are being sought:

1. How much plant food do the soils of South Dakota contain?

2. What yields may be expected from the present supply of plant food?

3. How long will the present supply of plant food last?

4. What elements of plant food, if any, are present in quantities too small to produce the maximum yield which might be expected under the climatic conditions prevailing in the various parts of South Dakota?

5. If plant food is lacking, in what form may it be most profitably applied to the soil?

6. What systems of farming are most profitable?

7. How may the fertility of the soils of South Dakota be increased and *permanently* maintained?

None of these questions has been fully answered, but the facts herein submitted have been ascertained by careful investigation and show how far the work has progressed.

WHERE THE WORK IS BEING DONE

Investigations are being made at:

1. The Brookings Station, Brookings County.
2. The Highmore Substation, Hyde County.
3. The Eureka Substation, McPherson County.
4. The Cottonwood Substation, Stanley County.

A detailed statement of the results of a complete fertility test at Brookings, extending over a period of five years is found on page 242 and the following pages. The results obtained at the Substations are given on page 260 and following pages.

PLANT FOOD

In view of the fact that this is the first South Dakota bulletin dealing with soil fertility, it seems proper to define some of the terms used and to state some of the principles involved.

Plant food consists of the materials upon which the plant feeds. A part of this food is taken from the air through the leaves of the plant and part of it from the soil through its roots.

The materials taken in through the leaves and roots undergo chemical changes within the plant and become root, stalk, leaves or grain. Every particle of the plant has been made from material taken by the plant from the soil or air.

It is well known that ten different chemical elements are necessary for plant growth. These ten elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, iron, sulphur. Without all of these elements present in sufficient quantities, no crop can be produced.

Hydrogen, oxygen and nitrogen are gases. Oxygen constitutes about one-fifth of the air. When oxygen is combined with hydrogen, water is formed. Nitrogen constitutes nearly four-fifths of the air, but is such an inert substance that it does not readily combine with anything else.

Carbon occurs in the form of charcoal, lampblack, graphite, the diamond. When it unites with oxygen, it forms a colorless gas known as carbon dioxide. This gas is met with in soda water from which it escapes when the pressure is removed. Carbon dioxide exists in small quantities in the air.

Potassium, calcium, iron and magnesium are metals. They readily combine with oxygen. Potassium combined with oxygen forms potash. Calcium combined with oxygen forms lime. Iron combined with oxygen forms the familiar iron rust—iron oxide. Magnesium combined with oxygen forms magnesia.

Phosphorus is a peculiar substance more or less familiar as a constituent of some kinds of matches. In its pure state it is kept under water to prevent its uniting with the oxygen in the air. When it unites with oxygen, it forms oxides of phosphorus. One of these oxides which contains two parts of phosphorus and five parts of oxygen is often incorrectly referred to as phosphoric acid. Phosphoric acid is made up of two parts of this oxide of phosphorus and three parts of water chemically combined.

Sulphur is familiar to nearly every one in its pure form. When it unites with oxygen, it forms sulphur dioxide and this chemically combined with water and one more part of oxygen forms sulphuric acid.

The plant gets its carbon from the air. The carbon dioxide referred to above, enters the leaves through small openings, and under the influence of the sunlight in the presence of the green coloring matter in the leaves, unites with water brought up from the soil to form starch, sugar, etc.

The hydrogen supply of the plant is derived from the soil water and much of the oxygen comes from the same source although some oxygen is taken from the air and some, in combination with other elements, from the soil.

The remaining seven elements of plant food are taken from the soil dissolved in the soil water. The dissolved food enters through the roots and is carried through the plant in the sap to be combined into materials which constitute the various parts of the plant.

THE AMOUNT OF THE VARIOUS PLANT FOOD ELEMENTS IN THE SOIL

Most soils, excepting the most barren, have a sufficient amount of the various elements of plant food to grow plants of one kind or another, but it frequently happens that one or more of these elements is present in quantities too small to produce paying crops.

When an element is found to limit the yield on account of being present in insufficient quantities to meet the demands of the crop, it is called a limiting element. The elements which have been found most frequently to be limiting elements are nitrogen, phosphorus, and potassium. For this reason our investigations have been limited to the study of these three elements in what are known as complete fertility tests.

PLAN OF THE WORK

At the several stations, the land is divided into blocks of slightly more than one acre each. These blocks are subdivided into plats containing exactly one-tenth of an acre. Each plat is separated from adjoining plats by an alley upon which no crop is grown and which is kept free from weeds.

The plats in the fertility test at each station are plowed at the same time and to the same depth; harrowed at the same time; planted at the same time with the same kind and amount of seed. There can then be no difference in yield arising from the preparation and seeding. The difference in yield must therefore, be explained by the amount of plant food applied.

APPLICATION OF PLANT FOOD

The method of applying plant food is illustrated in Figure 1. The first plat receives no plant food; the second receives nitrogen only; the third receives phosphorus only; the fourth receives potassium only; the fifth receives no plant food; the sixth receives nitrogen and phosphorus; the seventh receives nitrogen and potassium; the eighth receives phosphorus and potassium; the ninth receives nitrogen and phosphorus and potassium; the tenth receives no plant food. It will be seen that each element is applied separately, in combination with *each* of the other two, and in combination both of the other two,—all the combinations possible. The three plats receiving no plant food are situated one at each end and one in the middle of the acre, making it possible to compare the treated plats with the untreated plats and with each other. This method of comparison is used at Brookings and at the substations.

HARVESTING THE CROPS

The crop from each plat is harvested separately, threshed separately, and accurately weighed by experienced men. It is necessary to be accurate in order to obtain accurate information. Knowledge is valuable only in so far as it is *exact* knowledge.

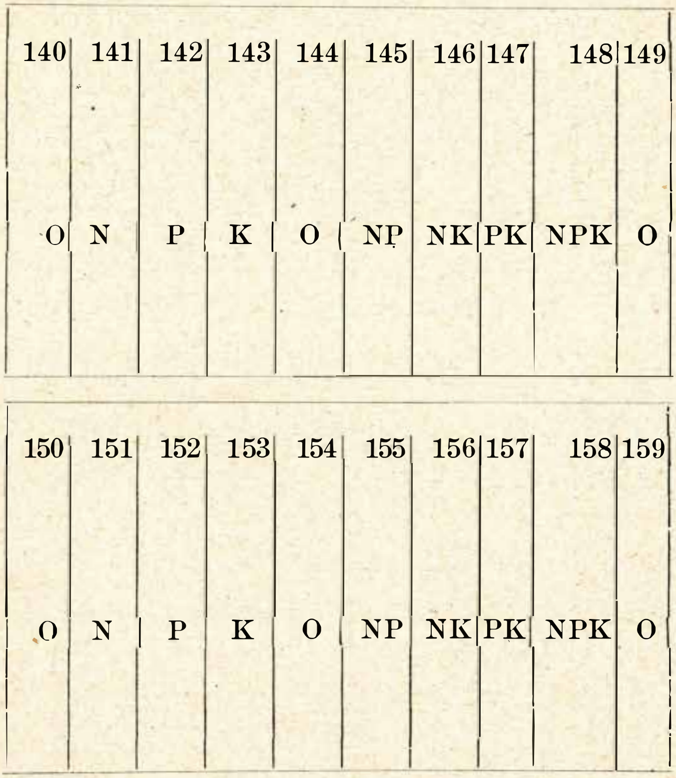

FIGURE 1.

PLAN OF THE COMPLETE FERTILITY PLATS AT BROOKINGS, SOUTH DAKOTA.

Each field is two rods wide and eight rods long, having an area of sixteen square rods—one-tenth of an acre. The fields are separated by an alley forty inches in width. These fields are located on the East Farm and extend from Number 140 at the south end to 159 at the north end of the series.

O means no plant food applied.

N means nitrogen applied.

P means phosphorus applied.

K means potassium applied.

N and P means nitrogen and phosphorus applied.

N and K means nitrogen and potassium applied.

P and K means phosphorus and potassium applied.

N, P and K means nitrogen, phosphorus and potassium applied.

On numbers 140 to 149 a rotation of corn, oats, wheat, barley, and clover is practiced.

On numbers 150 to 159 a rotation of corn, wheat, barley, oats, and clover is practiced.

THE WORK AT THE BROOKINGS STATION.

Investigations are being made upon two acres of land on the east farm at Brookings as shown in Figure 1. On the acre embracing plots 140 to 149 a rotation of corn, oats, wheat, barley, and clover is employed, while on the acre including plots 150 to 159, the rotation is corn, wheat, barley, oats and clover. All crops are removed and no manure has been applied to the soil.

The soil is a brown sandy loam to a depth of about fourteen inches underlain by a subsoil of clayey silt. The chemical analysis of soil from all the plots has not been completed but the average nitrogen content of the surface layer 6 2-3 inches deep over an acre, weighing about 2,000,000 pounds, is 6,325 pounds. The acid soluble phosphorus in the same amount of soil averages 1151 pounds. *Analyses for potassium, as far as completed, show that the soil contains 23,720 pounds of potassium per 2,000,000 pounds of soil.

This work was begun in 1908 and five years' results are, therefore, available. Nitrogen was applied prior to 1912 in the form of dried blood at the rate of 800 pounds per acre per year, except on the acre embracing plats 150 to 159, which received in 1911 only 680 pounds of dried blood. No record appears as to why the full amount was not applied. Phosphorus was applied prior to 1912 in the form of steamed bone meal or steamed bone meal tankage at the rate of 200 pounds of this material per acre per year. Potassium was applied prior to 1912 in the form of potassium sulphate at the rate of 100 pounds of the material per acre per year.

No chemical analysis of the materials is on record, but from materials remaining on hand in 1911 and said to have been the materials applied as plant food, it was found that the dried blood contained 11.64 per cent nitrogen; the steamed bone meal or tankage contained

*Note—Determinations of the total amount of phosphorus in the soil of each plat to a depth of 40 inches are being made.

TABLE N●. 1.
The Amount of Each Element of Plant Food Applied and Removed* in Five Years and the Amount Remaining

Treatment	Element	Plats 140-149 Removed In Grain Lbs.	Plats 140-149 Removed In Straw Lbs.	Plats 140-149 Total Lbs.	Plats 140-149 Applied Lbs.	Plats 140-149 Remaining Lbs.	Plates 150-159 Removed In Grain Lbs.	Plates 150-159 Removed In Straw Lbs.	Plates 150-159 Total	Plates 150-159 Applied Lbs.	Plates 150-159 Remaining Lbs.
None	N	104.57	34.73	139.30	0.00		125.63	30.08	155.71	0.00	
	P	18.43	6.28	24.71	0.00		23.28	5.78	29.06	0.00	
	K	20.75	69.79	90.54	0.00		27.86	62.29	90.15	0.00	
Nitrogen	N	123.32	39.47	162.79	424.27	261.48**	157.02	40.20	197.22	410.31	213.09
	P	21.63	6.95	28.58	0.00		29.41	8.06	37.47	0.00	
	K	24.29	80.07	104.36	0.00		35.03	87.14	122.17	0.00	
Phosphorus	N	122.43	33.29	155.72	0.00		128.93	36.92	201.85	0.00	
	P	24.09	6.67	30.76	81.44	50.68	30.82	7.39	38.21	81.44	43.23
	K	27.03	73.68	100.71	0.00		36.79	79.84	116.63	0.00	
Potassium	N	104.47	32.02	136.49	0.00		126.27	31.26	157.43	0.00	
	P	18.37	5.86	24.23	0.00		23.38	6.04	29.42	0.00	
	K	20.63	64.69	85.32	244.14	158.82	28.00	65.01	93.01	244.14	151.13
Nitrogen and Phosphorus	N	129.63	41.69	171.32	424.27	232.95	162.99	36.96	199.95	410.31	210.36
	P	22.75	7.42	30.17	81.44	50.27	30.98	7.39	38.37	81.44	43.07
	K	25.47	81.97	107.44	0.00		36.31	79.74	116.05	0.00	
Nitrogen and Potassium	N	125.80	41.43	167.23	424.27	257.04	135.03	34.60	169.63	410.31	240.68
	P	22.08	7.42	29.50	0.00		25.03	6.86	31.89	0.00	
	K	24.76	82.10	106.86	244.14	137.28	31.90	74.10	106.00	244.14	138.14
Phosphorus and Potassium	N	134.43	39.79	174.22	0.00		154.82	34.78	189.60	0.00	
	P	23.72	7.15	30.87	81.44	50.57	28.76	6.86	35.62	81.44	45.82
	K	26.60	79.00	105.60	244.14	138.54	34.48	73.85	108.33	244.14	135.81
Nitrogen, Phosphorus and Potassium	N	140.17	40.99	181.16	424.27	243.11	159.99	39.60	199.59	410.31	210.72
	P	24.84	7.33	32.17	81.44	49.27	29.92	8.11	38.02	81.44	43.31
	K	27.83	81.19	109.02	244.14	135.12	35.63	87.62	123.25	244.14	120.89

*The amount of plant food removed is calculated upon the basis that:

	Nitrogen	Phosphorus	Potassium
1 bu. of wheat contains	1.42 lbs.	.24 lbs.	.26 lbs.
1 cwt. of wheat straw contains	.50 lbs.	.08 lbs.	.90 lbs.
1 bu. of oats contains	.66 lbs.	.11 lbs.	.16 lbs.
1 cwt. of oats straw contains	.62 lbs.	.10 lbs.	1.04 lbs.
1 bu. of barley contains	.77 lbs	.16 lbs.	.19 lbs.
1 cwt. of barley straw contains	.32 lbs.	.08 lbs.	.88 lbs.
1 bu. of corn contains	1.00 lbs.	.17 lbs.	.19 lbs.

**In all probability more of the nitrogen applied has been lost from the soil than that removed in the crop.

Figure 2. View of the plats used in the complete fertility test at Brookings, South Dakota. In the foreground is the acre including plats 140-149 in wheat in 1912. Beyond the wheat the acre including plats 150-159 may be seen. The barley is in shock.

8.65 per cent phosphorus and 1.37 per cent nitrogen. The sample of potassium sulphate contained 40.69 per cent potassium.

For the crop of 1912, nitrogen was applied in the form of sodium nitrate, 350 pounds per acre, analyzing 15.23 per cent nitrogen. Phosphorus was applied in the form of "acid phosphate", 200 pounds per acre, analyzing 6.1 per cent phosphorus. Potassium was applied in potassium sulphate, 200 pounds per acre, analyzing 39.84 per cent potassium. For the details of the amounts of each element applied and removed, the reader is referred to Table Number 1.

RESULTS

In the following tables the yield of each crop grown on the two acres is given and the average for the number of crops is computed. The result for no treatment is the average in each case of the yields from the three untreated plats in the acre, except in the case of wheat in 1912, when the average is for two untreated plats. Nitrogen was applied, through an error, to one of the untreated plats in 1912. In the case of corn which was grown on both acres in 1910, the average for no treatment is from six plats and each of the other yields is the average yield for a given treatment for both acres.

From the tables it will be seen that the average yield of three crops of wheat on untreated soil is 10.4 bushels per acre. Nitrogen gave an increase of 2.83 bushels per acre per year. *Phosphorus produced an increase of 4.03 bushels per acre per year.* Potassium increased the yield 1.03 bushels per acre per year.

The three crops of barley show an average yield of 30.77 bushels per acre for untreated soil. The nitrogen application produced an increase of 9.33 bushels per acre per year. *Phosphoru sproduced an increase of 12.33 bushels per acre per year.* Potassium, however, effected an increase of only .56 bushels per acre per year. *The increase for phosphorus alone applied to the barley crop is greater than for any other treatment.*

Only two crops of oats have been produced and neither of these during a very favorable year. The crop in 1911 was almost a complete failure on account of the dry spring weather and early hot winds. The average yield for the two years on untreated soil was 16.44 bushels. Nitrogen increased the yield .26 bushels per acre per year. *Phosphorus increased the yield 2.16 bushels per acre per year.* Potassium increased the yield .36 bushels per acre per year. *The increase for phosphorus alone applied to the oats crop is greater than for any other treatment.*

In 1910 corn was grown on both acres. The average yield per acre for the six untreated plats was 46.53 bushels. Nitrogen increased the yield 8.17 bushels per acre. *Phosphorus increased the yield 21.2 bushels per acre.* Potassium decreased the yield 1.63 bushels. *The increase for Phosphorus alone was greater than for any other treatment.*

For some reason unknown to the writer, no clover was grown on the plats in 1909. Clover was seeded with the barley and oats in 1913 and will be given its proper place in the rotations hereafter.

TABLE NO. 2.

Results in the Complete Fertility Test at Brookings As Shown in the Yield of WHEAT Per Acre for Three Years.

Treatment	1908		1911		1912		Aver. 3 yrs		Av. Increase per Year	
	Bu. per acre	Straw lbs. per Acre	Grain Bu.	Straw lbs.	Grain Bu.	Straw lbs.	Grain Bu.	Straw lbs.	Grain Bu.	Straw lbs.
None	12.5	2933	5.83	767	12.9	1200	10.40	1633		
Nitrogen ...	14.1	3150	6.50	910	19.1	1990	13.23	2017	2.83	384
Phosphorus .	15.1	2380	5.20	740	23.0	2170	14.43	1763	4.03	130
Potassium...	13.5	2460	5.80	700	15.0	1310	11.43	1490	1.03	143D*
Nitrogen and phosphorus	16.33	3070	5.20	740	21.8	2150	14.44	1987	4.04	354
Nitrogen and potassium	16.00	3190	6.00	790	20.1	1990	14.03	1990	.37	357
Phosphorus & potassium	15.50	2820	5.00	600	22.5	2120	14.33	1847	3.93	214
Nitrogen, phosphorus & potassium	16.00	2990	4.70	720	25.8	2390	15.50	2033	5.10	400

*D means decrease.

TABLE NO. 3.

Results in the Complete Fertility Test at Brookings As Shown in the Yield of BARLEY Per Acre for Three Years.

Treatment	1908		1909		1911		Aver. 3 Yrs		Av. Increase	
	Grain bu	Straw lbs.	Grain bu.	Straw lbs.	Grain bu	Straw lbs.	Grain bu.	Straw lbs.	Grain bu.	Straw lbs.
None	31.30	1740	23.73	2493	37.27	1580	30.77	1938		
Nitrogen ..	47.20	3130	24.20	2540	48.90	2450	40.10	2707	9.33	769
Phosphorus	46.50	3110	29.80	2620	52.00	1980	43.10	2570	12.33	632
Potassium.	30.60	1780	22.50	2520	37.90	1760	31.33	2020	0.56	82
Nitrogen & phosphorus	43.30	2770	26.70	2670	55.80	2260	41.93	2567	11.16	629
Nitrogen & potassium	32.20	2690	26.00	2750	41.60	1850	33.27	2763	2.50	825
Phosphorus & potassium	40.60	2350	31.50	2690	49.30	2060	40.47	2367	9.70	429
Nitrogen, phosphorus & potassium	43.30	3420	32.10	2660	52.50	2620	42.63	2900	11.86	962

TABLE No. 4

Results in Complete Fertility Test at Brookings, as Shown in the Yield of Oats, per Acre, for Two Years.

Treatment	1909		1911		Average		Aver Increase	
	Grain bu.	Straw lbs.	Grain bu	Straw lbs.	Grain bu.	Straw lbs.	Grain bu.	Straw lbs.
None	30.23	2517	2.66	982	16.44	1750		
Nitrogen	30.60	2870	2.80	910	16.70	1891	0.26	146
Phosphorus	35.00	2730	2.20	930	18.60	1830	2.16	80
Potassium	31.20	2650	2.40	825	16.80	1738	0.38	12D*
Nitrogen and Phosphorus	30.60	2770	1.40	1105	16.00	1938	0.44D	188
Nitrogen and Potassium	31.20	2600	2.00	1085	16.60	1848	0.16	98
Phosphorus and Potassium	34.40	2850	1.70	1045	18.05	1948	1.61	198
Nitrogen, Phosphorus and Potassium ..	31.6	2690	1.60	900	16.60	1795	0.16	45

*D means decrease.

TABLE No. 5

Results in the Complete Fertility Test at Brookings, As Shown in the Yield of CORN Per Acre, for One Year.

TREATMENT	1910 Grain bu.	1910 Stalks lbs.	Increase Grain bu.
None	46.53	No Record	
Nitrogen	54.70	No Record	8.17
Phosphorus	58.55	No Record	12.02
Potassium	44.90	No Record	1.63D
Nitrogen and phosphorus	56.55	No Record	10.02
Nitrogen and potassium	51.15	No Record	4.62
Phosphorus and potassium	55.45	No Record	8.92
Nitrogen, phosphorus and potassium	57.25	No Record No Record	10.72

D means decrease.

Table Number 6 shows in detail the yield from each plat in the two rotations for the five years.

In the consideration of crop yields on the Brookings plats, as well as the yields at the several substations, the reader will be interested in the rainfall table on page 263.

TABLE No. 6

Bushels of Grain and Pounds of Straw Per Acre Produced Upon the Plats in the Complete Fertility Test At Brookings.

PLAT	1908 Wheat Grain bu.	1908 Wheat Straw lbs.	1909 Barley Grain bu	1909 Barley Straw lbs.	1910 Corn Grain bu.	1910 Corn Stalks lbs.	1911 Oats Grain bu.	1911 Oats Straw lbs	1912 Wheat Grain bu.	1912 Wheat Straw lbs.
O 140	12.8	3510	20.88	2550	51.3	NO RECORD	3.3	1045	18.5*	1840*
N 141	14.1	3150	24.20	2540	55.8		2.8	910	19.1	1990
P 142	15.1	2380	29.80	2620	58.5		2.2	930	23.0	2170
K 143	13.5	2460	22.50	2520	45.1		2.4	825	15.0	1310
O 144	12.2	2760	22.70	2460	47.0		2.8	1010	12.8	1150
NP 145	16.3	3070	26.70	2670	54.0		1.4	1105	21.8	2150
NK 146	16.0	3090	26.00	2759	53.2		2.0	1085	20.1	1990
PK 147	15.5	2820	31.50	2690	55.1		1.7	1045	22.5	2120
NPK 148	16.0	2990	32.10	2660	55.8		1.6	900	25.8	2390
O 149	12.5	2530	27.70	2470	47.1		1.9	891	13.0	1250
	1908 Barley		1909 Oats		1910 Corn		1911 Wheat		1912 Barley	
O 150	35.7	1910	31.6	2440	44.2	NO RECORD	5.5	870	38.7	1470
N 151	47.2	3030	30.6	2870	53.6		6.5	910	48.9	2150
P 152	46.5	3110	35.0	2730	58.6		5.2	740	52.0	1980
K 153	30.6	1780	31.2	2650	44.7		5.8	700	37.9	1760
O 154	28.7	1770	29.1	2420	46.0		6.0	690	35.2	1540
NP 155	43.3	2770	30.6	2770	59.1		5.2	740	55.8	2260
NK 156	32.2	2690	31.2	2600	49.1		6.0	790	41.6	1850
PK 157	40.6	1350	34.4	2850	55.8		5.0	600	49.3	2060
NPK 158	43.3	3420	31.6	2690	58.7		4.7	720	52.5	2620
O 159	29.5	1640	30.0	2690	43.6		6.0	740	37.9	1720

*Through an error, nitrogen was applied to this plat in 1912.

N means nitrogen applied; P means phosphorus applied; K means potassium applied.

From a study of these tables, it may be seen that,

(1) Nitrogen produced an increase in the yield in all crops.

(2) Phosphorus produced a greater increase in all crops.

(3) Potassium produced a very small increase in the yield of small grains and an actual decrease in the yield of corn.

(4) In all crops, except wheat, phosphorus alone produced greater increases than any other treatment.

These facts in connection with the soil analysis stated on page 242 show almost beyond question that phosphorus is the limiting element in the soil under consideration.

There was phosphorus enough available in the soil to produce an average of 10.40 bushels of WHEAT per acre for the three crops of wheat. *The addition of phosphorus to the soil increased the yield of wheat as an average to 14.43 bushels, an increase of 4.03 bushels per acre per year, or 38.7 per cent.*

There was available phosphorus enough in the soil to produce 30.77 bushels of BARLEY per acre as an average for three years. *The addition of phosphorus increased the yield of barley to 43.1 bushels as an average for the same length of time, an increase of 40.5 per cent.*

There was available phosphorus enough in the soil to produce 16.44 bushels of OATS per acre for two years, while the addition of *phosphorus increased the yield to* 18.6 *bushels per acre per year, or 13 per cent.*

There was available phosphorus enough in the soil to produce 46.53 bushels of CORN per acre in 1910. The addition of *phosphorus increased the yield to 58.55 bushels per acre, an increase of 12.02 bushels per acre, or 25.8 per cent.*

Summarizing the results of five years' work at Brookings, it is found that:

1. *Phosphorus increased the yield of wheat 38.7 per cent.*

2. *Phosuhorus increased the yield of barley 40.5 per cent.*

3. *Phosphorus increased the yield of oats 13.0 per cent.*

4. *Phosphorus increased the yield of corn 25.8 per cent.*

The supply of phosphorus in the soil is limited. There is no system of farming by which more phosphorus may be added to the soil in any way except by purchasing it. With the removal of phosphorus from the soil, as shown in Table No. 1, the land must become less and less fertile. *No system of crop rotation can maintain the fertility of the soil.*

While uitrogen increased the yield, it did not produce the maximum yields and is not yet the limiting element in the soils tested, but owing to the relatively large quantities of this element removed in the crops (see Table No. 1), its scarcity in the near future will undoubtedly limit the increased yields now made possible through the use of phosphorus.

Unlike phosphorus, the nitrogen content of the soil may be increased without purchasing it. *Every ton of clover hay takes forty pounds of nitrogen from the air and every ton of alfalfa takes fifty pounds from the air* through the assistance of the bacteria that live on the roots of these plants. Hence, by growing these crops or other legume crops and returning them to the soil, either directly, or after they have been transformed into manure, the supply of nitrogen in the soil may be maintained, provided, of course, that a sufficient amount of legumes is grown.

All results show that there is enough potassium in the soil for the needs of the crops. The increase for potassium is small in any case, and the best authorities maintain that potassium applied in the form of potassium sulphate may liberate some phosphorus from the soil, thus acting as a stimulant. In these results the effects of potassium, whether direct or indirect are almost negligible. There is no need of purchasing potassium.

IMPROVEMENT OF THE BROOKINGS BROWN SANDY LOAM.

From the facts here submitted, the improvement of soil like that at Brookings may be accomplished by

1. *Applying sufficient phosphorus to meet the needs of the crops which may be grown under the prevailing climate conditions.*

2. *By including sufficient legume crops in the rotation practiced to maintain the nitrogen supply, and returning as much organic matter to the soil as possible.*

This method will maintain the fertility of the soil indefinitely and secure for coming generations a productive soil—a soil not despoiled of its fertility by the shortsightedness of their ancestors.

(NOTE: When the soil becomes acid, the acidity may be corrected by the application of lime alone.)

PROFIT AND LOSS

The facts set down in the following pages will be of assistance in ascertaining whether or not the increase in yields through the application of plant food can be secured at a profit. There is no question as to whether an increase can be secured. It can be secured. Can it be secured at a profit to the farmer?

Table Number 7 shows the cost of the various materials containing plant food. In the first column is given the price per ton f. o. b. South St. Paul, Minnesota; in the second column, the cost laid down in Brookings in less than carload lots, freight rate 32 cents per hundred; in the third column, the cost laid down in Brookings in carload lots of forty thousand pounds, freight rate 13 cents per hundred.

TABLE No. 7

***Cost of Materials Used in Fertility Test**

	Cost per ton f. o. b. South St. Paul, Minn.	Cost per ton in Brookings less than carload lots	Cost per ton in Brookings carload lots
Dried blood	$57.00	$63.40	$59.60
Nitrate of soda..	67.00	73.40	69.60
Steamed Bone meal	25.00	31.40	27.60
Acid Phosphate .	20.00	26.40	22.60
Potassium Sulphate	55.00	61.40	57.60

*The company quoting these prices made the statement that they are in effect now (May 23, 1913) and have been all this season.

Tables, numbers 8, 9, 10 and 11, show the values of each kind of crop for each year that it was grown, and also the average value of each crop for all the years that it was grown. The reader may compare the value of the various crops with the several treatments which the soil producing them has received.

TABLE No. 8—WHEAT

Farm value of wheat crops per acre, grain only, in the complete fertility test at Brookings, South Dakota. The prices given are those prevailing in South Dakota, December 1st, following the production of each crop, according to the Year Book of the United States Department of Agriculture.

TREATMENT	1908 92c	1911 91c	1912 69c	Total for Wheat	Average Value per Acre per Year
None	$11.50	$ 5.31	$ 8.90	$25.71	$ 8.57
Nitrogen	12.97	5.92	13.28	32.17	10.72
Phosphorus	13.89	4.73	15.87	34.49	11.50
Potassium	12.42	5.58	10.35	28.35	9.45
Nitrogen and phosphorus	15.02	4.73	15.04	34.79	11.60
Nitrogen and potassium	14.72	5.46	13.87	34.05	11.35
Phosphorus and potassium	14.26	4.55	15.53	34.34	11.45
Nitrogen, phosphorus and potassium	14.72	4.28	17.80	36.80	12.27

TABLE No. 9—BARLEY

Farm value of barley crop per acre, grain only, in the complete fertility test at Brookings, South Dakota. Prices are those prevailing in South Dakota December 1st, following the production of each crop, according to the Year Book of the United States Department of Agriculture, and the Crop Reporter of January, 1913.

TREATMENT	1908 47c per bu	1909 45c per bu	1912 42c per bu.	Total	Average Value per Acre per Year
None	$14.71	$10.68	$15.65	$41.04	$13.68
Nitrogen	22.18	10.89	20.54	53.61	17.87
Phosphorus	21.86	13.41	21.84	56.11	18.70
Potassium	14.30	10.13	15.92	40.35	16.78
Nitrogen and phosphorus	20.35	12.02	23.44	55.81	18.94
Nitrogen and potassium	15.13	11.70	17.47	44.30	14.77
Phosphorus and potassium	19.08	14.18	20.71	43.97	14.66
Nitrogen, phosphorus and potassium	20.35	14.45	22.05	56.85	18.95

TABLE No. 10—OATS

Farm value per acre of oats crops, grain only, in the complete fertility test at Brookings, South Dakota. The prices are those prevailing in South Dakota, December 1st, following the production of each crop, according to the Year Book of the United States Department of Agriculture.

TREATMENT	1909 34c per bu.	19 1 43c per bu.	Total Value	Average Value per Acre per Year
None	$10.28	$ 1.14	$11.42	$ 5.71
Nitrogen	10.40	1.20	11.60	5.80
Phosphorus	11.90	.95	12.85	6.43
Potassium	10.61	1.03	11.64	5.82
Nitrogen and phosphorus	10.40	.60	11.00	5.50
Nitrogen and potassium	10.65	.86	11.51	5.76
Phosphorus and potassium	11.70	.73	12.43	6.22
Nitrogen, phosphorus & potassium	10.74	.69	11.43	5.72

TABLE No. 11—CORN

Farm value per acre of the corn crop, grain only, in the complete fertility test at Brookings, South Dakota. The price given is that prevailing in South Dakota, December 1, 1910, according to the Year Book of the United States Department of Agriculture.

TREATMENT	1910 40c per Bu.
None	$18.61
Nitrogen	21.88
Phosphorus	23.42
Potassium	17.96
Nitrogen and phosphorus	22.62
Nitrogen and potassium	20.46
Phosphorus and potassium	22.18
Nitrogen, phosphorus and potassium	22.90

Table Number 12 shows the value of the grain produced under each treatment in both rotations for each of the five years; the total value of the grains produced under each treatment for the five years; the total value of the increase; and the value of the average annual increase for each treatment.

TABLE No. 12

Value Per Acre of All Crops Produced Under Each Treatment at Brookings During Five Years.

TREATMENT	1908 Wheat	1909 Barley	1910 Corn	1911 Oats	1912 Wheat	Total	Total Increase	Average Increase Per Yr	Average Annual Increase for Both Rotations
None	$11.50	$10.68	$19.39	$ 1.14	$ 8.90	$51.61			
Nitrogen	12.97	10.89	22.32	1.20	13.28	60.66	$ 9.05	$ 1.82	$ 2.58
Phosphorus	13.89	13.41	23.40	.95	15.87	67.52	15.91	3.18	3.59
Potassium	12.42	10.13	18.04	1.03	10.35	51.97	.36	.07	.11
Nitrogen and phosphorus	15.02	12.02	21.60	.60	15.04	64.28	12.67	2.53	3.14
Nitrogen and potassium	14.72	11.70	21.28	.86	13.87	62.43	10.82	2.16	1.85
Phosphorus and potassium	14.26	14.18	22.04	.73	15.53	66.74	15.13	3.03	2.97
Nitrogen, phosphorus & potassium	14.72	14.45	22.32	.69	17.80	69.98	18.37	3.67	3.55
	Barley	Oats	Corn	Wheat	Barley				
None	14.71	10.28	17.79	5.31	15.65	63.74			
Nitrogen	22.18	10.40	21.44	5.92	20.54	80.48	16.74	3.35	
Phosphorus	21.86	11.90	23.44	4.73	21.84	83.77	20.03	4.01	
Potassium	14.30	10.61	17.88	5.58	15.92	64.29	.75	.15	
Nitrogen and phosphorus	20.35	10.40	23.64	4.73	23.44	82.56	18.82	3.76	
Nitrogen and potassium	15.13	10.65	19.64	5.46	17.47	71.59	7.75	1.55	
Phosphorus and potassium	19.08	11.70	22.32	4.55	20.71	78.36	14.62	2.92	
Nitrogen, phosphorus & potassium	20.35	10.74	23.48	4.28	22.05	80.90	17.16	3.43	

Table Number 13 shows the profits and losses resulting from the application of plant food. The results are calculated for the farmer who might wish to buy plant food in small quantities and for him who might wish to buy in carload lots. *An examination of the data recorded in this table reveals the fact that no application of plant food except phosphorus alone paid any profit,* and that the average value of the crops produced on the *phosphorus* plats of both rotations *was 31.1 per cent greater* than the average value of the crop produced on the untreated plats of both rotations for a period of five years.

In the case of the first rotation, the GAIN per acre per year was 14 cents and 52 cents, according to the quantity in which the phosphorus was purchased. It is estimated that the cost of hauling the phosphorus from the railroad station to the farm and distributing it over the field, is 40 cents per acre per year. *If this cost be subtracted from the gains of 14 cents and 52 cents the results are a loss of 26 cents in the first case and a gain of 12 cents per acre in the second case*

In the case of the second rotation, the GAIN for *phosphorus alone* per acre per year was *96 cents and $1.34,* according to the quantity purchased. If from this amount the cost of applying the phosphorus is subtracted, the *gains are 56 cents and 94 cents per acre respectively.*

TABLE No. 13

Statement of Profits and Losses in the Fertility Test at Brookings, S. D. Total Values for Five Years. All on the Acre Basis.

Rotation of Corn, Oats, Wheat and Barley.

TREATMENT	Value of Grain	Value of Increase	Cost of Plant Food		Total Gain of Loss		Average Annual Gain of Loss	
			Local Freight	Car-load Lots	Local Freight	Car-load Lots	Local Freight	Car-load Lots
None	$51.61							
Nitrogen	60.66	$ 9.05	$114.28	$107.53	$105.23L	$ 98.48L	$21.05L	$19.69L*
Phosphorus	67.52	15.91	15.20	13.30	.71G	2.61G	.14G	.52G
Potassium	51.97	.36	18.42	17.28	18.06L	16.92L	3.61L	3.28L
Nitrogen and phosphorus	64.28	12.67	129.48	120.83	116.81L	108.16L	23.36L	21.63L
Nitrogen and potassium	62.43	10.82	132.70	124.81	121.88L	113.99L	24.37L	22.80L
Phorphorus and potassium	66.74	15.13	33.62	30.58	18.49L	15.45L	3.70L	3.09L
Nitrogen, phosphorus and potassium	69.98	18.37	147.90	138.11	129.53L	119.74L	25.90L	23.95L
Rotation of Corn, Wheat, Barley, Oats								
None	$63.74							
Nitrogen	80.48	16.74	110.51	103.99	93.77L	87.25L	18.77L	17.45L
Phosphorus	83.77	20.03	15.20	13.30	4.83G	6.73G	.96G	1.34G
Potassium	64.29	.75	18.42	17.28	17.67L	16.53L	3.53L	3.30L
Nitrogen and phosphorus	82.56	18.82	125.71	117.29	106.89L	98.47L	21.37L	19.69L
Nitrogen and potassium	71.49	7.75	128.93	121.27	121.18L	113.52L	24.23L	22.70L
Phosphorus and potassium	78.36	14.62	33.62	30.58	19.00L	15.96L	3.80L	3.19L
Nitrogen, phosphorus and potassium	80.90	17.16	144.13	134.57	126.97L	117.41L	25.39L	23.48L

*G means Gain; L means Loss.

The average gain per acre per year for these two rotations is therefore, 15 cents and 75 cents, according to the quantity of phosphorus purchased. These amounts must pay for the increased cost of harvesting, threshing and marketing the larger crop.

Reference to Table Number 1 shows that *81.44 pounds of phosphorus was applied* to the phosphorus plats during the five years and that only 30.76 *pounds of phosphorus was removed* in the first rotation, *leaving on deposit 50.68 pounds* of the element for furture use. In the second rotation, *38.21 pounds of phosphorus was removed, it 50.68 pounds* of the element for future use. In the average amount of the phosphorus applied remaining unused is 46.95 pounds per acre. The high yielding plats, therefore, contain 46.95 pounds more phosphorus than they did five years ago—enough to supply the necessary amount of this element for more than six crops such as those already removed.

The average amount of phosphorus removed from the untreated plats was 26.88 pounds. These plats are, therefore, poorer in this element than they were five years ago, while those which produced 31.1 per cent more grain are richer than they were at the beginning of the investigation.

In considering the actual profits, the condition of the soil after the crops have been removed must be considered. *A large part of the wealth thought to have been produced by South Dakota farmers during the last few decades is the result of removing fertility from the soil without making a corresponding return.*

Even at the high price paid for the phosphorus used in this investigation, the investment may be considered profitable if the condition of the soil is considered. If phosphorus can be bought in a cheaper form and plowed under with organic matter larger profits may be expected.

The cheapest form in which phosphorus can be bought is in the form of finely ground rock phosphate. Phosphorus in this form is being used successfully in many places in the United States at this time. *Whether or not it can be so used in South Dakota will be determined by the facts ascertained from investigations recently begun at the South Dakota Experiment Station. Whatever the results may be, whatever relation the cost of phosphorus the cost of crop production and the market value of crops may bear to one another, one fact remains—phosphorus has been the limiting element in crop production on the plats at Brookings during the last five years, and unless this element can be supplied, the soil will grow poorer and poorer with the removal of each succeeding crop.*

OTHER FERTILITY INVESTIGATIONS AT BROOKINGS, S. D.

In addition to the complete fertility test discussed in the preceeding pages, the following investigations are being pursued at the Brookings Station:

1. A grain farming system in which all grain is sold and all straw and stalks are returned to the soil with and without phosphorus and potassium singly and in combination.

2. A stock farming system in which all grains and hay are fed and the manure returned to the soil with and without phosphorus and potassium singly and in combination.

3. A test of the comparative efficiency of acid phosphate and rock phosphate as sources of phosphorus.

4. The effect of ground limestone on crop yields.
5. The effects of green manures and stable manures.

FERTILITY TESTS AT HIGHMORE, HYDE COUNTY, S. D.

Six acres of land, each divided into ten plats, are used in a complete fertility test at Highmore. The rotation employed is alfalfa, corn, wheat, legume, grain sorghum, and oats. All crops are grown each year. Plant food is applied here in the same manner as at Brookings Station.

Plant food was applied to two acres only in 1911. Owing to the severe drought no crops were produced. In 1912 plant food was applied to all plats. The results are shown in Table Number 14. The application of plant food resulted in a loss in every case.

No definite conclusion can be drawn from these two years' results. The reader may infer that plant food will not produce crops in the absence of sufficient rainfall.

TABLE No. 14.

Results From Complete Fertility Test at Highmore, Hyde County, South Dakota—Yield Per Acre.

TREATMENT	Wheat 1911 Bu.	Oats 1911 Bu.	Corn 1912 Bu.	Wheat 1912 Bu.	Peas[1] (Hay) 1912 Lbs.	Kowliang[2] 1912	Oats[3] (Straw) 1912
None	Failure	Failure	16.56	0.5	500	Failure	753
Nitrogen	Failure	Failure	11.25	0.25	500	Failure	520
Phosphorus	Failure	Failure	8.05	0.75	500	Failure	810
Potassium	Failure	Failure	14.40	0.90	500	Failure	830
Nitrogen and phosphorus	Failure	Failure	10.75	0.35	500	Failure	1300
Nitrogen and potassium	Failure	Failure	10.50	0.21	500	Failure	1250
Phosphorus and potassium	Failure	Failure	14.10	0.10	500	Failure	900
Nitrogen, phosphorus and potassium	Failure	Failure	15.80	0.06	500	Failure	550

1. No seed produced on account of dry weather. The plots were mowed and yielded ¼ ton each of pea hay mixed with weeds.
2. Kowliang seed did not germinate. The acre was seeded to millet, but this also failed on account of dry weather.
3. Owing to the dry weather the oats were cut for hay.

FERTILITY TESTS AT EUREKA, McPHERSON COUNTY, S. D.

Three acres of land, each divided into ten plats, are used in the complete fertility test at the Eureka Substation. The rotation employed is corn, wheat, and peas. The plant food is applied in the regular manner already described.

Plant food was applied for the first time for the crop of 1912. The results are shown in Table Number 15. A period of hot winds injured the wheat and peas so that the results are not very significant. There is an increase of nearly seven bushels of corn where phosphorus and potassium, and where nitrogen, phosphorus and potassium were applied. However, the untreated plat next to the plat receiving all three elements yielded sixty bushels. The land is quite rolling at the Eureka Substation and no definite conclusion can be drawn from the results of one year except that the application of plant food in every case resulted in loss.

TABLE No. 15.

Results From Complete Fertility Test at Eureka, McPherson County, S. D.—Yields Per Acre.

Treatment	Corn Bu.-1912	Wheat Bu.-1912	Peas Bu.-1912
None	47.80	1.67	6.77
Nitrogen	47.10	0.83	3.66
Phosphorus	46.70	0.58	1.66
Potassium	37.40	0.33	2.66
Nitrogen and phosphorus	47.40	0.50	3.33
Nitrogen and potassium	46.70	0.17	2.17
Phosphorus and potassium	54.60	1.08	2.33
Nitrogen, phosphorus and potassium	54.50	2.17	6.50

These plats are situated on rolling land and are somewhat uneven.

FERTILITY TESTS AT THE COTTONWOOD SUBSTATION, STANLEY COUNTY, S. D.

The complete fertility test is confined to three acres of land at the Cottonwood Substation, each acre being divided into tenth acre plats. The rotation employed is corn, wheat, and peas. All crops are grown every year. Plant food is applied in the regular manner.

This work was begun in 1912 and Table Number 16 shows the results obtained. The yields for wheat and peas show a decrease for all treatments, while the yield of corn shows a slight increase on the plats receiving potassium. No definite conclusion can be drawn from this first year's work. The application of plant food resulted in loss in every case.

TABLE No. 16.

Results From Complete Fertility Test at Cottonwood, Stanley County, S. D.—Yields per Acre.

Treatment	Corn Bu.-1912	Wheat Bu.-1912	Peas Bu.-1912
None	26.92	9.44	7.33
Nitrogen	23.12	9.33	3.67
Phosphorus	22.75	8.67	4.00
Potassium	29.00	8.33	5.67
Nitrogen and phosphorus	24.75	6.50	3.33
Nitrogen and potassium	29.12	5.83	4.00
Phosphorus and potassium	28.63	7.83	6.00
Nitrogen, phosphorus and potassium	27.12	8.16	5.33

RAINFALL AT THE SEVERAL STATIONS

	Brookings						Cottonwood			Eureka				Highmore				
	1907	1908	1909	1910	1911	1912	1910	1911	1912	1909	1910	1911	1912	1908	1909	1910	1911	1912
Jan. ..	1.06	0.20	1.20	1.07	0.61	0.28	0.66	T	0.17	0.10	0.60	0.50	0.25	T	0.26	0.82	0.11	0.13
Feb. ..	0.28	1.80	1.57	0.40	0.53	0.24	0.97	0.15	0.05	0.45	1.70	0.73	0.40	0.53	0.34	0.19	0.39	0.11
Mch. ..	0.55	1.16	0.37	0.35	0.53	0.26	0.76	T	3.00	0.14	1.23	0.62	1.05	0.00	0.13	0.58	2.54	0.27
Apr. ..	1.67	2.10	1.16	2.34	1.62	3.36	1.06	0.85	3.32	0.50	0.82	2.24	1.29	1.35	0.30	1.40	0.32	1.05
May ..	2.36	6.46	4.85	0.87	1.90	6.98	2.54	1.10	1.18	2.65	0.42	0.97	3.37	2.68	4.72	0.94	2.31	2.20
June ..	5.65	6.35	2.29	1.85	3.78	2.09	1.30	0.64	0.95	3.35	3.80	1.29	1.50	5.78	1.69	3.74	0.09	1.31
July ..	3.77	4.69	2.44	1.68	3.32	2.52	1.11	0.59	2.42	2.21	0.53	0.43	2.19	2.49	1.81	0.85	2.69	1.44
Aug. ..	1.41	2.37	3.39	2.46	3.81	4.68	0.48	2.41	3.42	1.39	2.60	3.57	3.27	3.53	3.74	0.66	2.52	3.39
Sept. ..	1.28	3.89	1.67	0.96	3.08	1.61	0.82	3.59	1.30	1.25	3.65	1.15	1.43	0.62	1.70	0.89	3.06	0.71
Oct. ..	0.96	1.43	1.71	0.38	5.12	0.96	0.32	1.15	0.11	0.17	0.18	0.61	0.07	2.19	1.04	0.24	1.05	0.20
Nov. ..	0.10	1.30	0.65	0.17	0.23	0.00	0.53	0.20	T	0.60	T	0.88	T	1.39	0.71	0.40	0.35	0.00
Dec. ..	1.12	0.42	1.14	0.10	0.42	0.20	3.00	0.42	0.12	2.40	0.25	0.80	0.11	0.31	1.41	0.44	0.44	0.35
Total ..	20.21	32.17	22.44	12.63	24.95	23.18	12.65	11.10	16.04	15.21	15.78	13.79	14.93	20.87	17.85	9.05	15.87	12.06

AVAILABLE BULLETINS:

90. Tankage and other By-Products for Pigs; Shrunken Wheat for Swine.
91. Co-Operative Vegetable Tests in 1904; Peas, Beans, Sweet Corn, Cabbage.
94. Alfalfa and Red Clover.
95. The Treatment of Nail Pricks of the Horse's Foot.
96. Forage Plants and Cereals at Highmore Sub-Station.
97. Speltz and Millet for the Production of Baby-Beef.
98. Crop Rotation.
99. Macaroni and Durum Wheats. A continuation of Bulletin 92.
100. The Value of Speltz for the Productio nof Beef and Pork.
101. Forage Plants at the Highmore Sub-Station, 1906.
103. Breeding Hardy Strawberries.
104. Breeding Hardy Raspberries.
105. Stock Food for Pigs.
106. Sugar Beets in South Dakota.
107. Sheep Scab.
108. New Hybrid Fruits.
109. Russ of Cereals and other Plants.
110. Progress in Variety Tests of Oats.
111. A Study of South Dakota Butter with Suggestions for Improvement.
112. The Killing of Mustard and other Noxious Weeds in Grain Fields by the use of Iron Sulphate.
113. Progress in Variety Tests of Barley.
114. Digestion Coefficients of Grains and Fodders for South Dakota.
115. Report of Work for 1907 and 1908 at Highmore Sub-Station.
116. Acidity of Creamery Butter and its Relation to Quality.
117. Sugar Beets in South Dakota.
118. Corn
121. Sugar Beets in South Dakota.
122. Creamery Butter.
123. Milk Powder Starters in Creameries.
124. Progress in Grain investigations.
125. Fattening Steers of Different Ages.
126. Alkali Soils.
127. Breeding and Feeding Sheep.
128. Progress in Wheat Investigations.
129. Growing Pedigreed Sugar Beet Seed in South Dakota.
130. Some New Fruits.
131. Scabies (Mange) in Cattle.
132. Effects of Alkali Water on Dairy Products.
133. Alfalfa as a Field Crop in South Dakota.
134. More Winter Dairying in South Dakota.
135. Trials with Millets and Sorghums for Grain and Hay in South Dakota.
136. Fattening Pigs.
137. Wintering Steers.
138. Hog Cholera.
139. Soil and Crop and Their Relation to State Building.
140. Selection and Preparation of Seed Potatoes in the Season of 1912.
141. Co-Operative Tests of Alfalfa from Siberia and European Russia.
142. Sugar Beets in South Dakota—Results to Date.
143. Roughage for Fattening Lambs.
144. Preliminary Report on the Milking Machine.
145. A Report of Progress in Soil Fertility Investigations.