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Thirty Years of Soil Fertility Investigations in South Dakota

J. G. Hutton

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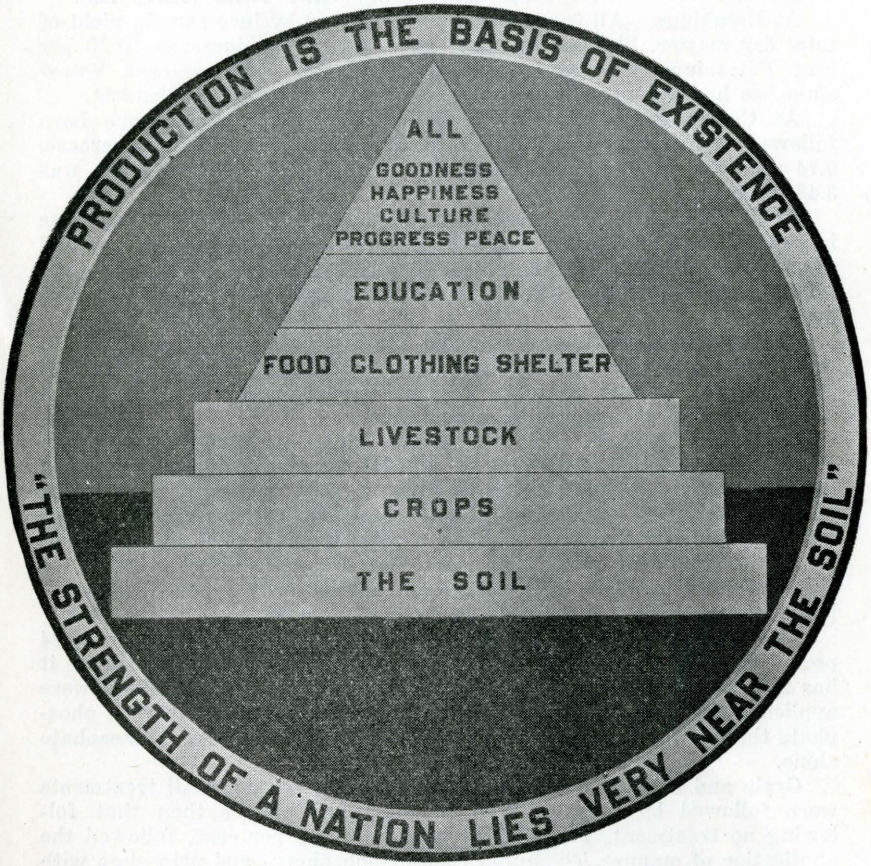

The Pyramid of Human Achievement in the Circle of Time

AGRICULTURAL EXPERIMENT STATION
South Dakota State College of Agriculture and Mechanic Arts
AGRONOMY DEPARTMENT
Brookings, S. Dak.

Summary of Bulletin

The complete fertility trials in which nitrogen, phosphorus, and potassium were applied singly and in combination resulted as follows:

Total Amount of Dry Matter Produced Based Upon the Yield Following No Treatment as 100

	Yrs.	O	N	P	K	NP	NK	PK	NPK
Brookings	30	100	112.82	127.59	101.55	116.95	107.72	121.02	121.24
Cottonwood	25	100	96.52	105.25	109.74	108.22	106.55	102.41	108.39
Eureka	25	100	98.45	93.30	93.72	98.19	96.34	97.16	100.78
Highmore	2[illegible]	100	104.54	104.14	97.48	116.83	108.03	103.64	113.93

At Brookings.—All treatments were followed by increases in yield of total dry matter. Phosphorus alone gave the largest increase, 27.59 per cent. Potassium alone gave the smallest increase, 1.55 per cent. Potassium has had a depressing effect when applied with other elements.

At Cottonwood.—All treatments except nitrogen alone have been followed by increases in yield of total dry matter. The largest increase, 9.74 per cent, followed potassium. The decrease following nitrogen was 3.48 per cent.

At Eureka.—The only treatment which was followed by an increase in yield of total dry matter was nitrogen, phosphorus and potassium, and the increase, 0.78 per cent, is too small to be significant. The lowest yield followed the application of phosphorus alone and the decrease was 6.70 per cent.

At Highmore.—Increases in yield of total dry matter followed all treatments except potassium alone where a decrease of 2.52 per cent is recorded. The largest increase, 16.83 per cent, followed the application of nitrogen and phosphorus in combination.

Manure, Phosphate and Limestone Trials at Brookings.—For 25 years the application of 10 tons of manure per acre every four years in the rotation was followed by an increase in yield of total dry matter of 17.14 per cent. The application of acid phosphate with manure increased the yield 2.17 per cent over manure, a total increase over the yield following no treatment of 19.31 per cent. This was the largest increase for any treatment applied. Rock phosphate applied with manure seems to have decreased the beneficial effects of manure alone by 3.17 per cent.

Limestone when applied alone was followed by an increase of 2.34 per cent, but when applied with manure or manure and acid phosphate it has reduced the beneficial effects observed where these substances were applied without limestone. Where limestone was applied with rock phosphate there is an apparent increase of 0.62 per cent over rock phosphate alone.

Grain and Livestock Farming Systems at Brookings.—All treatments were followed by higher yields of total dry matter than that following no treatment. The largest increase, 13.64 per cent, followed the application of manure. The application of phosphorus and potassium with manure gave lower yields than manure alone.

Plowing under crop residues with sweet clover and peas did not prove as effective as manure. The application of phosphorus and phosphorus and potassium with the residues has increased the yields over those following the residues alone but has not equalled the yields following manure alone.

The amount of water required to produce one pound of dry matter on the plots receiving no treatment was: Brookings, 1,593 pounds; Cottonwood, 2,086 pounds; Eureka, 1323 pounds; and Highmore, 1,638 pounds.

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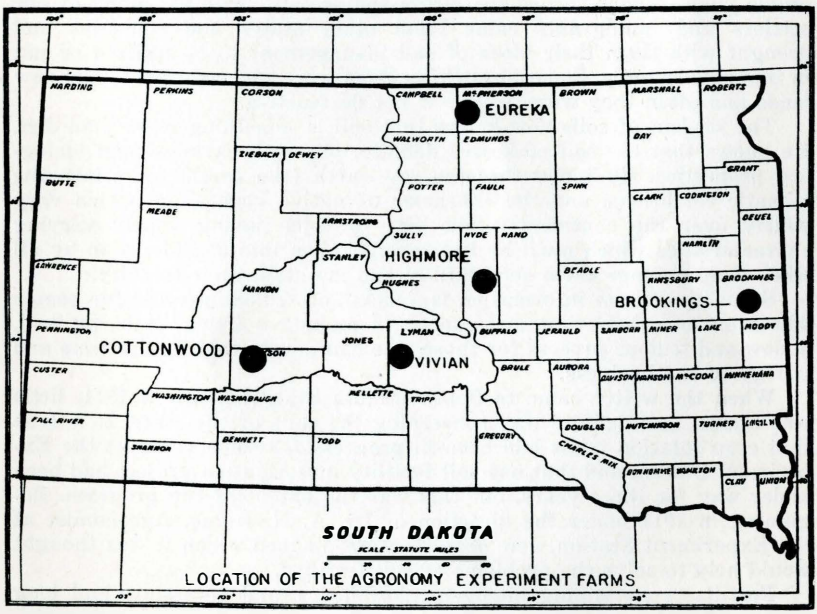

Foreword

Maintaining productivity of the soil is, without doubt, the most important material problem of any nation. The basic needs of humanity—food, clothing, shelter, and fuel—are, with the exception of fuel, obtained almost exclusively from the soil, not forgetting, of course, that the waters of the earth furnish important items of food to many people.

When the soil fails to produce abundantly humanity suffers physical, moral and civic deterioration. Progressive, happy and prosperous nations are never hungry, ragged or cold, and their advancement depends largely upon whether or not they are able so to manage their soils that the physical needs of their people are satisfied. Famine, pestilence and war follow in the wake of depleted soils. These facts have been known since the dawn of civilization, but nevertheless they do not seem to have received the universal consideration which they deserve.

Thinking people who have long occupied the soils of a certain region have often learned something of the means of maintaining their productivity, but this is not always true, as the abandoned lands of our own nation can mutely testify. When good land was abundant and to be had for the occupancy many people thought it easier to move to these new lands than to conserve their own. The time of cheap productive lands is past in-so-far as America is concerned. We must live upon the land which we already possess. This land must supply the needs of this generation as well as the needs of the generations to come. The soil is our most precious possession.

The soils of South Dakota are relatively new soils. Some of our venerable pioneers who turned the virgin sod are still with us. Many of our settlers and immigrants came from other states and countries and brought with them their ideas of soil management to be utilized or not in this new country. Sometimes these ideas were well adapted to the new lands and often they were useless if not destructive.

The student of soils now knows that soil is something more than dirt. He knows that the soil possesses definite, physical, chemical and biological properties. He knows that the raw earth (the parent material), the climatic conditions, and the character of native vegetaiton, which vary widely over the continents, give rise to soils having widely varying characteristics which must be known and taken into consideration by all who would manage them successfully and maintain their fertility.

Securing definite information is a slow and tedious process for people who must use their time and energy in making a living. It is, as well, a slow and tedious process for those who can devote their entire time and energy to the business.

When the writer came to South Dakota State College in 1911, little was known in a definite way concerning the soils of the state. It is true that crop rotation trials had been in progress for some years at the Experiment Station and that one soil fertility investigation project had been under way for three years, but this was the extent of the program. Beginning in 1911 under the direction of Dr. A. N. Hume, Agronomist at the Experiment Station, new projects were planned which it was thought would help to solve the problems of soil fertility.

Fertilizers containing nitrogen, phosphorus, and potassium had long been used on soils deficient in these elements—elements which are essen-

tial to the growth of all crops. However, no one knew whether the soils of South Dakota were in need of additional quantities of any of these elements which were known to be lacking in many of the soils of the world and in the eastern states of our union. Consequently, projects were planned for the experiment farm at Brookings and for the experiment substations at Cottonwood, Eureka, and Highmore. (See map on page ?? for location of these stations.) The results obtained from field trials with fertilizers at the several stations are reported in this bulletin.

The quest has been long and sometimes discouraging because of lack of sufficient appropriations to pursue the work effectively. But we have never lost faith and have received much moral support and encouragement from many people, some of whom have long since passed to the Great Beyond. Such support has kept us going, slowly to be sure, when going seemed all but impossible.

It requires 30 years to secure 30 years results from field trials. There is no short cut. Seasons vary from flood to drought while hail, and wind, and insects, and rust have their days as well.

In soil research work all the varying factors which affect the growth of crops should be under control. As a matter of fact, few of them are under control of the investigator. In these investigations it was possible to choose definite crop varieties, to establish so some extent definite crop rotations and tillage practices. It has been possible, with one exception, to apply definite amounts of fertilizers to the soil. This was the factor most easily controlled. Other factors varied from year to year. But perhaps the duration of these projects has been great enough that the constant factor of plant food (fertilizer) application dominates other varying factors in the average crop yields following certain soil treatments. At least, that is our hope.

All of the facts are published in detail and in many summaries for the convenience of the reader who may wish to analyze them and arrive at his own conclusions. If the reading of this bulletin seems tedious, just remember that the writer and some of his associates have spent 27 years of continuous effort in making the facts available. The reader may be assured that many of the facts here published will help in the solution of his soil fertility problems if he will study diligently to apply them.

Acknowledgement

The writer wishes to acknowledge the generous collaboration of all the members of the Agronomy Department who for 27 years have labored to make it possible to accumulate the data here published. All of the experiment station foremen have been faithful in carrying out the field directions and in harvesting, weighing and recording the yields. Verification in this office of every crop yield has found an unbelievably small number of errors in their records and every evidence of their loyalty and their intense interest in the work.

The list of workers is too long to publish, but special mention should be made of Experiment Station Foreman S. W. Sussex and Mrs. Sussex at Highmore who were on duty before the writer arrived in 1911 and who have been in continuous service to this day. Mrs. Sussex has kept the

weather records at Highmore through all the years. The writer acknowledges gratefully the services of the various clerks and stenographers who have at times assisted in tabulating the material and especially the service of Miss Frances E. Peterson who has assisted in the verification and tabulation of all the field results and in the preparation of the manuscript.

PRECIPITATION RECORD, BROOKINGS, S. D

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1889	1.05	1.20	0.16	1.02	1.50	1.48	2.92	0.72	2.70	T	0.35*	0.94	14.04
1890	.65	.15*	.56	.79	3.35	7.91	1.54	2.07	.45	0.43	.30	.80	18.98
1891	.10	1.00	.60	2.23	.84	4.09	2.01	1.38	.48	1.07	.25	2.30	16.35
1892	.35	.36	.54	3.15	7.32	3.52	3.69	3.03	1.49	.53	.22	.32	24.82
1893	.30	.86	2.34	3.00*	2.85	1.54	.68	1.70	.56	.44	.04	.27	14.58
1894	.11	.05	1.23	3.04	.30	1.30	.09	.73	1.68	2.36	.19	.14	11.22
1895	.25	.17	.66	2.41	3.50	3.84	3.79	2.15	3.24	.00	1.02	.03	21.06
1896	.13	T	.52	6.26	3.45	3.82	2.00	.44	1.90	1.83	.78	.25	21.38
1897	1.60	.30	.44	2.45	.83	3.86	4.32	3.59	3.17	1.48	.58	.34	22.92
1898	.00	.55	.40	.88	5.15	1.94	1.56	2.78	1.31	1.25	.59	.00	16.41
1899	.25	.21	.40	3.36	3.38	5.42	.73	3.25	.17	2.21	.42	.43	20.23
1900	.02	.20	2.09	1.68	1.25	1.62	4.94	4.00	4.97	2.72	.45	.64	24.56
1901	.09	.28	.50	1.40	1.80	4.51	1.66	2.94	5.09	.74	.60	.15	19.76
1902	.50	.26	.67	1.60	2.66	3.17	2.75	5.30	.26	1.18	.96	2.52	21.83
1903	.10	.28	1.87	1.00	4.53	4.16	3.30	4.25	2.73	1.85	.10	.45	24.62
1904	.04	.15	.25	1.78	1.82	4.30	1.91	.93	.93	3.15	.02	.20	15.48
1905	.22	1.00	.68	1.01	6.14	6.09	.98	4.54	2.16	1.50	2.45	T	26.77
1906	.17	.02	.58	1.40	3.51	4.89	1.86	4.28	5.13	3.01	.89	.52	26.26
1907	1.06	.28	.55	1.67	2.36	5.65	3.77	1.41	1.28	.96	.10	1.12	20.21
1908	.20	1.80	1.16	2.24	6.46	6.35	4.69	2.37	3.89	1.43	1.30	.42	32.31
1909	1.10	1.57	.37	1.16	4.75	2.29	2.44	3.39	1.77	1.71	.65	1.14	22.34
1910	1.08	.40	.35	2.34	.87	1.85	1.68	2.46	.96	.38	.17	.10	12.64
1911	.61	.53	.55	1.62	1.90	3.78	3.32	3.81	3.08	5.07	.24	.42	24.91
1912	.28	.24	.71	3.36	6.98	2.09	2.52	4.68	1.61	.96	T	.20	23.63
1913	.02	.09	.45	2.24	3.50	1.96	2.99	1.33	1.55	1.55	.81	.09	16.58
1914	.22	.40	.42	1.64	4.16	6.67	1.62	3.16	3.32	2.21	T	.33	24.15
1915	.18	1.12	.18	2.03	2.12	3.28	3.04	3.52	2.68	1.37	.28	.62	20.42
1916	1.47	.32	.50	2.95	3.70	4.27	.40	2.03	.84	.45	.03	.36	17.32
1917	1.43	.50	1.20	3.19	3.08	3.49	2.03	1.20	2.89	.12	.07	.31	19.53
1918	.19	.14	.44	1.28	3.40	1.85	3.95	4.19	.72	1.56	1.61	1.09	20.42
1919	.07	.63	.73	1.90	3.87	9.30	5.60	1.48	1.69	1.14	1.35	.10	27.86
1920	.34	.24	1.85	2.95	3.84	7.27	5.45	2.15	1.99	.66	1.30	.30	28.34
1921	.09	.05	1.49	1.42	2.99	.85	3.44	2.11	4.25	.27	.50	.10	17.56
1922	.40	1.73	.79	.42	1.82	3.75	2.81	1.70	.36	.81	3.08	.20	17.87
1923	.27	.07	.29	3.00	2.59	5.74	1.94	3.03	1.73	1.41	.23	.23	20.53
1924	.10	.31	1.34	1.82	1.32	6.88	1.22	3.89	1.02	.84	.11	.35	19.20
1925	.45	.06	.22	1.88	.49	7.17	1.26	.64	.77	.26	.57	.33	14.10
1926	.40	.06	.14	.15	1.44	3.64	3.14	1.46	2.10	.89	.56	.63	14.59
1927	.14	.35	.83	4.04	4.29	1.46	4.88	.35	1.98	.49	.49	1.10	20.40
1928	.09	.30	.44	.96	.53	2.97	2.69	4.52	1.37	1.68	.78	.15	16.48
1929	.96	.45	.68	3.32	2.11	1.12	3.25	2.33	4.80	2.41	.04	.07	21.54
1930	.42	.40	.25	1.25	2.04	1.68	.27	1.50	3.38	1.84	2.01	.10	15.14
1931	.03	.04	.30	1.33	.68	2.42	1.62	3.24	2.00	1.11	1.89	1.07	15.73
1932	.54	.13	.27	1.34	2.23	3.07	2.34	4.07	2.07	.81	.32	.24	17.43
1933	.07	.18	1.08	.98	1.44	.67	1.42	2.10	3.82	.05	.09	.50	12.40
1934	.21	.05	.47	.14	1.49	4.77	3.56	.82	4.58	1.26	.38	.18	17.71
1935	.52	.16	1.47	3.47	2.11	2.75	1.66	4.19	.04	.23	.43	.62	17.45
1936	.53	1.16	.76	1.54	3.49	3.13	.20	3.86	1.34	.04	.30	.57	16.92
1937	.45	.26	2.03	3.19	1.70	2.39	1.16	2.28	.55	1.11	.31	.76	16.19
AV.	.40	.43	.76	2.03	2.81	3.71	2.48	2.60	2.09	1.24	.62	.49	19.657

* Interpolated. T indicates trace of precipitation, less than .01 inch.

Plate I.—The Monthly and Annual Precipitation at Brookings, S. D., 1889 to 1937

Part I
Soil Fertility Investigations at Brookings, S. D.
Section 1. Complete Fertility Test

Introduction.—The results here reported from the complete fertility tests have been obtained from investigations carried on under an experiment station project known as "Adams Agronomy Project No. 1, The Effect of Crop Rotations: Complete Fertility Test." The funds supporting this work are allotted from appropriations by the Federal government under the Adams act, the allotment being made by the director of the experiment station.

History.—The project was begun while Prof. C. Willis was station agronomist, 1908-1910. After his resignation in November, 1910, the work was carried on by assistants until June, 1911, when Dr. A. N. Hume became station agronomist. Since July 1, 1911, the writer has been concerned with the details of the project.

Earlier reports on this project have appeared in bulletins No. 145 and No. 280, South Dakota Agricultural Experiment Station.

Object.—The purpose of this project is to determine

(1) The effect of producing crops on the plant food content of the soil as indicated by the crop yields and the chemical analyses of the soil, and

(2) The effect upon the yield of crops grown of applying certain elements of plant food to the soil.

It is particularly with the latter phase of the work that this report is concerned.

Plan of the Work.—This project was probably the first to deal with the soil fertility problem in the Northwest and was modeled after systems of soil fertility investigations in the older agricultural areas of America and in foreign countries. In these areas it had been found that the three elements of plant food most likely to be present in the soil in quantities too small to meet the needs of the growing crops are nitrogen, phosphorus and potassium. For this reason the plan of this project involved these three elements, and they have been applied singly and in all possible combinations in quantities supposedly adequate to maintain and even increase the original supply in the soil against the loss due to the removal of definite quantities of the several elements in the crops grown.

No organic matter is plowed under in this project except the stubble of the several crops.

The original plan has been followed almost exactly in the belief that significant and valuable information can be secured only by pursuing a definite plan of investigation through many years. It is needless to say that there have been suggestions and even temptations to alter the original plan, but always the conclusion has been reached that if the plan should be changed there would be unanswerable questions arising concerning the results obtained.

The crops in the rotations are staple crops widely grown in South Dakota, and the varieties which have been grown for many years are those which were found to be the best yielding varieties after years of field tests. While other varieties of some of the crops are now thought to be slightly better than those named on page 9 it has been thought best to retain the original varieties in the test in so far as possible, lest the

introduction of new varieties might seem to modify the results and to confuse the crop factor with the soil factor in production. It is the soil factor that is under investigation in this project.

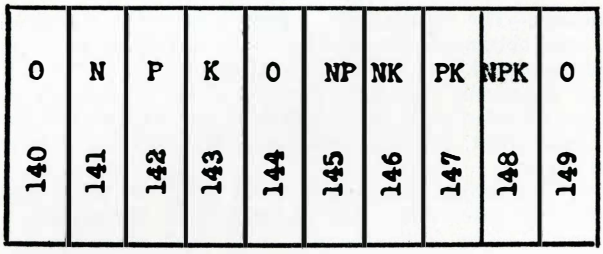

Fig. 1.—Plan of the Complete Fertility Plots at Brookings, South Dakota

Each plot is two rods wide and eight rods long, having an area of sixteen square rods —one tenth of an acre. The plots are separated by alleys forty inches in width. They are located on the East Farm, plot 140 being at the south end of the series and plot 159 at the north end.

The letters indicate the kind of fertilizer applied to the several plots:

O means nothing applied; often referred to as "None."
N means nitrogen applied in nitrate of soda at the rate of 350 pounds per acre.
P means phosphorus applied in acid phosphate at the rate of 200 pounds per acre.
K means potassium applied in potassium chloride at the rate of 200 pounds per acre.

Each letter has a uniform meaning whether it occurs alone or in combination with other letters.

Figure 1 shows the general plan of the complete fertility test field and in the explanation the rotations practiced and the fertility applied are indicated. It will be noted that the corn crop occurs on both acres the same year and that the red clover crop also occurs on both acres the year preceding the corn crop. The other crops, wheat, oats and barley, never occur on both acres the same year.

It is possible to compare the results obtained from these rotations and to determine the effect of the succession of crops upon the yields, but no attempt will be made to analyze the results from this standpoint in this report.

Soil.—The soil on the plots involved in this project is weathered from the glacial till deposited by the Kansan ice sheet. Although the surface layer has no doubt been somewhat modified by the action of the wind the material is not strictly loessial. The soil type is Barnes sandy loam.

The soil profile is that of the tschernozem, or dark colored soil, of the regions of limited rainfall, such as the Great Plains of America and similar climatic areas in the U.S.S.R. (Russia).

The surface or "A" horizon extends to a depth of about 14 inches and consists of a very dark grayish brown sandy loam. At the lower limit of this horizon, or layer, pebbles and even boulders, sometimes of large size, are found in the grayish yellow weathered till which also contains a considerable amount of silt and clay mixed with the pebbles and sand. The pebbles and boulders do not predominate, but are noticeable when taking soil samples with an auger.

Below 14 inches and varying somewhat in depth there is a definite calcium carbonate or "lime" accumulatiton which is characteristic of the "B" horizon of soils of this group. This soil belongs definitely in the great group of soils now coming to be known as pedocals or calcium carbonate accumulating soils. These soils must be considered as definitely distinguished from the soils of regions having heavier rainfall where all calcium carbonate is removed from the soil profile by percolating water. In the region of dark colored, calcium carbonate accumulating soils the removal of soluble material from the soil profile by percolating water is negligible.

The composition of the surface layer to a depth of seven inches as determined from the samples taken in 1908 averaged for the 20 plots as follows:

Total Nitrogen 0.31677 per cent or 6,335 lb. in 2,000,000 lb. of soil.
Total Phosphorus 0.06655 per cent or 1,330 lb. in 2,000,000 lb. of soil.
Total Potassium 1.37925 per cent or 27,585 lb. in 2,000,000 lb. of soil.

Two million pounds, 1,000 tons, is the approximate weight of a layer of soil seven inches deep over one acre.

Application of Plant Food.—Nitrogen is applied in the form of nitrate of soda at the rate of 35 pounds per plot, or 350 pounds per acre. Phosphorus is applied in the form of 16 per cent acid phosphate at the rate of 20 pounds per plot, or 200 pounds per acre. Potassium is applied in the form of potassium chloride at the rate of 20 pounds per plot, or 200 pounds per acre. During the early years of the work, 1909-1914, potassium sulphate was applied at the rate of 200 pounds per acre. During the European war it was impossible to secure potassium salts and no potassium was applied from 1915 to 1918. Since 1919 potassium has been applied as potassium chloride at the rate of 200 pounds per acre.

The fertilizers are applied each year in the five year rotation except the year that the land is in red clover, when no fertilizers are applied. The fertilizers are applied broadcast in the spring before seeding the grain crops before harrowing the fall-plowed land.

Crops Grown.—The crops employed in the two rotations are:

Corn: Brookings, S. D. No. 86
Wheat: Acme S. D. No. 284, except Mindum S. D. 1160 in 1936-7
Barley: Odessa S. D. No. 182
Oats: Sixty day S. D. No. 165
Clover: Medium Red S. D. grown

Harvesting Crops.—The crops from the several plots have been harvested separately, threshed separately, the grain and straw carefully weighed, and the weights recorded. However, the corn stalks were not weighed in 1910; at least there is no record of such weights. The corn has been harvested from the standing stalks and the stalks cut and weighed afterwards. The recorded weight of stalks is, therefore, no doubt less than the actual weight, as some of the leaves were blown away before the stalks could be cut and weighed.

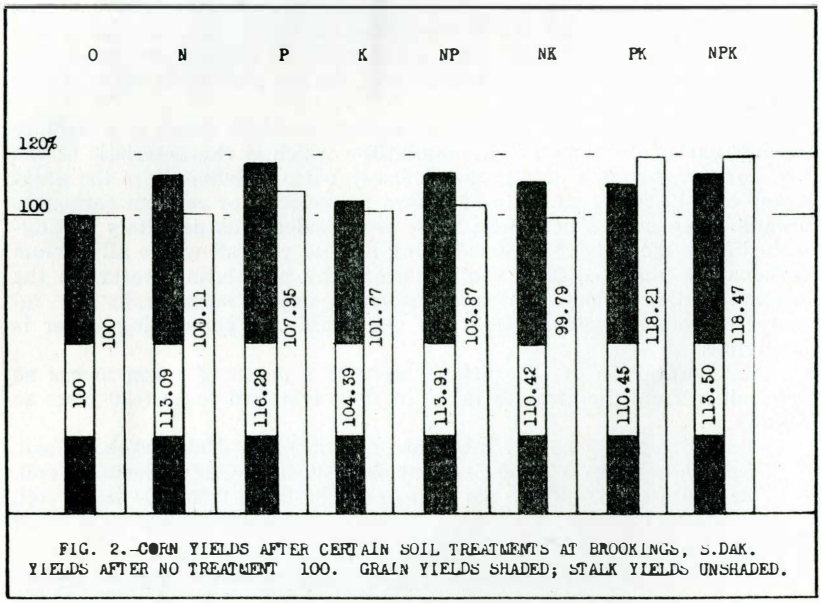

FIG. 2.—CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S.DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

Yields.—In the following tables the yields of the several crops for each year grown and the average yields of each crop and of all crops for all the years grown are recorded.

Corn—Table No. 1 shows that the average yield of corn for the six years when this crop was grown was, for the untreated plots, 29.18 bushels per acre. The average yield of stalks for the five years when stalks were weighed was 1,862 pounds per acre. See page 20.

The greatest average increase in yield for any treatment over the yield of the untreated plots was 4.75 bushels of grain, or 16.28 per cent, for phosphorus alone, and 344 pounds of stalks, or 18.47 per cent, for nitrogen, phosphorus and potassium. A careful examination of the table will indicate the yield as influenced by the application of the several elements of plant food singly and in combination.

The comparative yields of grain and stalks, in per cent, are shown graphically in Figure 2.

Wheat—Table No. 2 shows the yields of wheat for 15 years. The average yield of grain for the untreated plots is 13.67 bushels per acre and of straw 1,906 pounds per acre. See page 20.

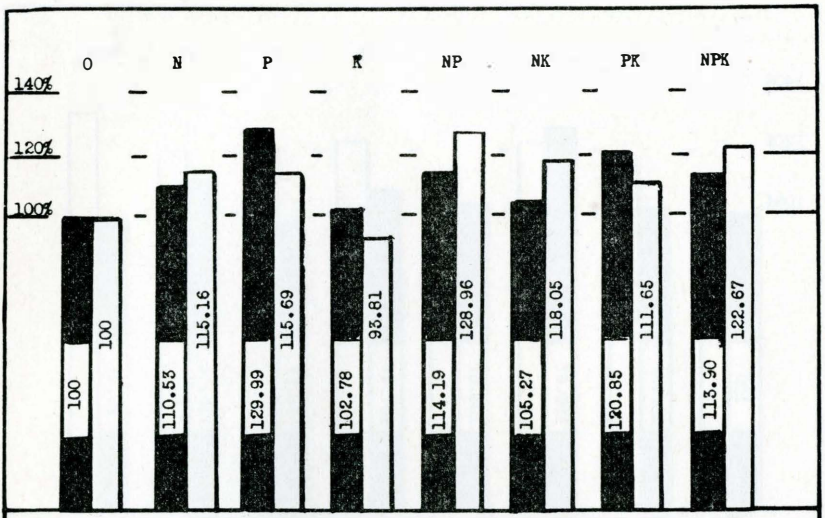

FIG. 3.-WHEAT YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

The greatest increase in the average yield of grain follows the application of phosphorus, 4.10 bushels per acre, or 29.99 per cent, while the greatest average increase in straw is 552 pounds per acre, or 28.96 per cent, for nitrogen and phosphorus.

The comparative yields of grain and straw, in per cent, for the several treatments are shown graphically in Figure 3.

Oats—Table No. 3 shows the average yields of oats following the several treatments. The average yield of oats for 14 years was, for the untreated plots, 27.73 bushels of grain and 1,244 pounds of straw per acre. The largest increase in average yield of grain, 7.95 bushels per acre, or 28.67 per cent, follows the application of phosphorus, while the greatest average increase in straw, 425 pounds per acre, or 34.16 per cent, follows the application of nitrogen, phosphorus, and potassium. See page 21.

The comparative yields of grain and straw, in per cent, are shown graphically in Figure 4.

Barley—Table No. 4 shows the yields of barley for 15 years. The average yield of grain on the untreated plots was 26.37 bushels and the average yield of straw was 1,434 pounds per acre. The greatest increase in average yield of grain, 9.53 bushels per acre, or 36.14 per cent, follows the application of phosphorus, while the greatest increase in yield of straw, 673 pounds per acre, or 46.93 per cent, follows the application of nitrogen, phosphorus, and potassium. See page 21.

The comparative yields of grain and straw, in per cent, for the several soil treatments are shown graphically in Figure 5.

Red Clover.—Tables No. 5 and No. 6 show respectively the average yields of red clover seed, straw and hay for the five years that clover was

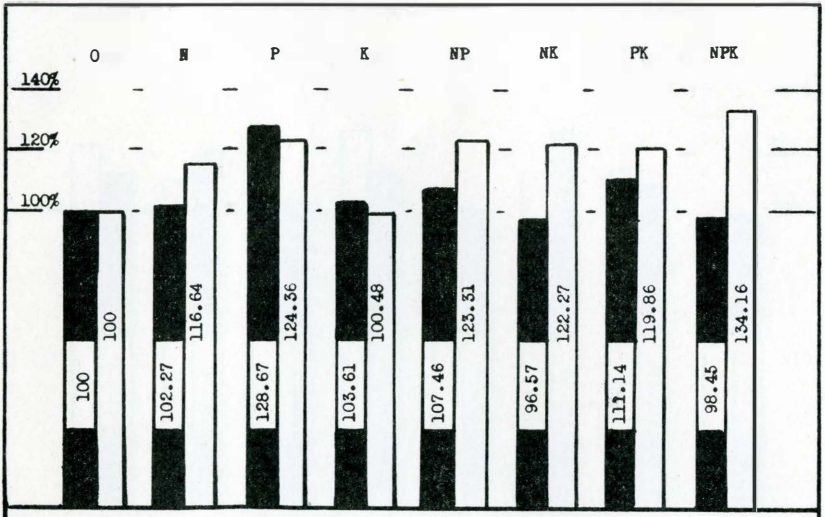

FIG. 4.-OATS YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S.DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

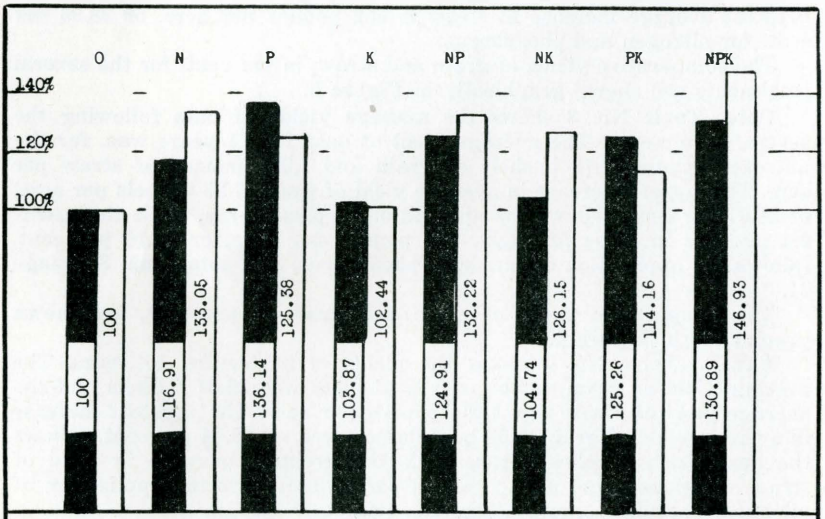

FIG. 5.-BARLEY YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S.DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

grown on both acres. It is the practice to cut the first growth of red clover for hay and to harvest the second growth for seed. However, in 1919 no seed formed in the second growth and it was cut for hay instead of seed. See pages 22 and 23.

The average yield of red clover seed per acre for the five years, including the two years when the yield was zero, was, for the untreated plots, 40 pounds while the average weight of the straw was 767 pounds per acre. The greatest average increase per acre, 27 pounds, or 67.50 per cent, follows the application of phosphorus, and the greatest increase in weight of straw, 349 pounds or 45.50 per cent, follows the applicaton of phosphorus and potassium.

The average yield of hay per acre for all cuttings for the five years, from the untreated plots, was 1,461 pounds. The greatest average increase in yield of hay per acre, 1,194 pounds, or 81.72 per cent, follows the application of phosphorus. It should be said that the hay on plots receiving nitrogen contained many non-leguminous weeds and for this reason the yields recorded do not indicate the actual yield of clover.

The comparative yields of clover seed, straw and hay, in per cent, for the several soil treatments are shown graphically in Figure 6.

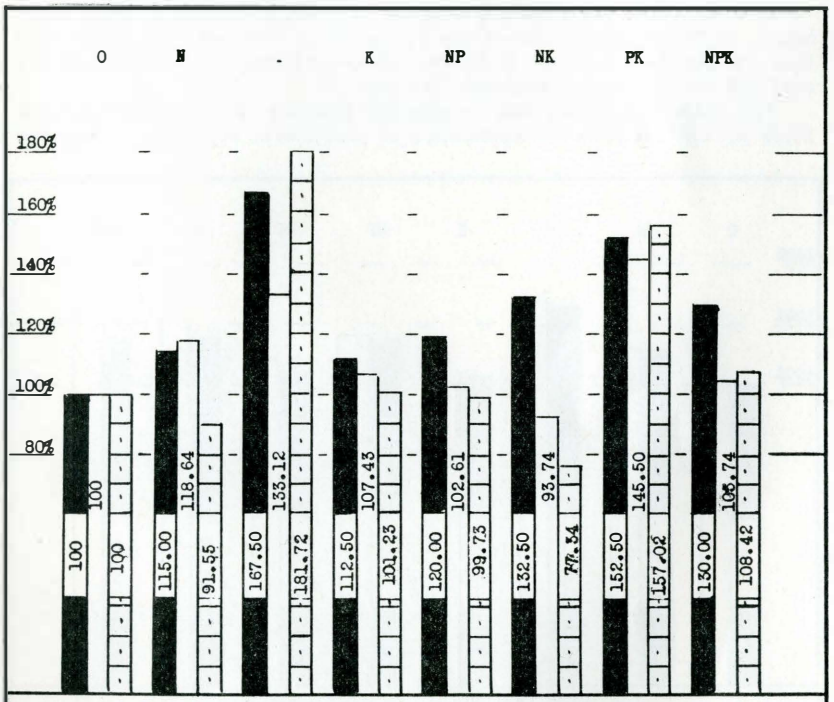

FIG. 6.-RED CLOVER YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. SEED YIELD SHADED; STRAW YIELD UNSHADED; HAY BARRED

Recapitulation.—Table No. 7 shows for each crop grown the average yields of grain, straw, stalks, and hay, and the average increases and decreases following each of the different applications of plant food in both rotations for the entire period, 1908 to 1937. The average increases or decreases in per cent as compared with the yields from plots receiving no treatment are also shown.

For convenience in referring to the table, the largest average increases are printed in bold face type for each crop. See page 22.

Summary of Yields.—Table No. 8 is a record of the total weights on the acre basis of all crops grown on plots 140-149 and 150-159 for the 30 years 1908-1937, inclusive. These figures include the weights of grain, clover seed, straw, stalks and hay for each treatment. The total increases for all of the crops for the several treatments for 30 years and the average per year also are recorded. The percentage increases in yield for the several treatments over the yields from the untreated plots on the basis of total weights likewise are recorded. The number of years each crop was grown and harvested on the two acres plots 140-149 and plots 150-159, is indicated. The grain yields are for 30 years but straw, stalks, and hay have been recorded for only 29 years as there is no record of the weight of corn stalks in 1910.

It is seen that the greatest increase in grain yield for all crops combined, 26.26 per cent, follows the application of phosphorus alone, and that the greatest increase in straw, stalks and hay combined, 28.43 per cent follows the same treatment. See page 24.

This table also shows that the greatest increase of total crop produced, 27.59 per cent, follows the application of phosphorus alone. By adding the

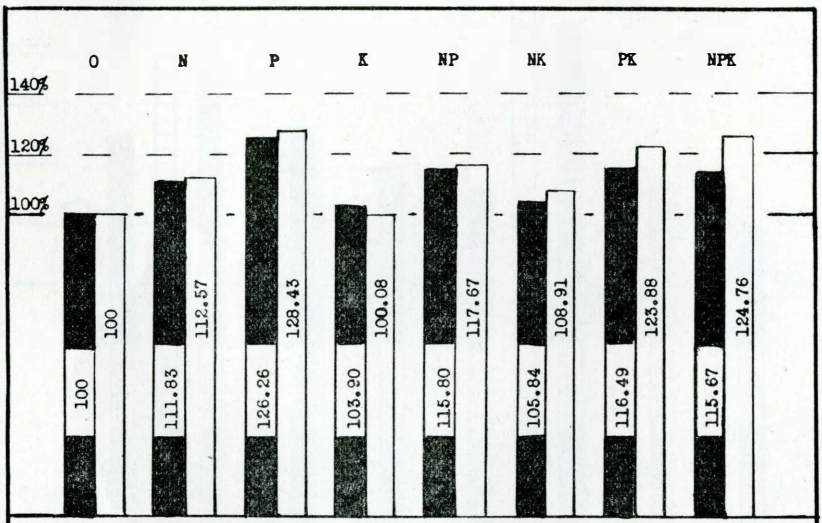

FIG. 7.-COMPARATIVE TOTAL WEIGHTS OF SEEDS, AND STRAW, STALKS, AND HAY OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW, STALKS, AND HAY YIELDS UNSHADED.

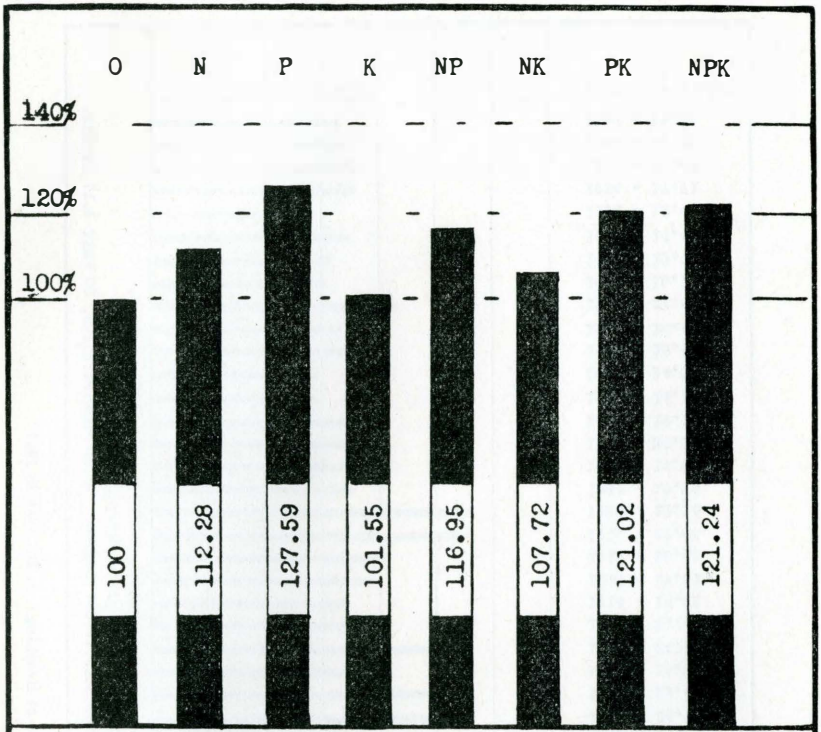

FIG. 8.-TOTAL WEIGHTS OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. CORN, OATS, WHEAT, BARLEY, AND RED CLOVER FOR 30 YEARS.

average annual increase in yield in grain due to phosphorus, namely, 274.3 pounds, to the weight of the average annual increase in yield of straw, stalks, and hay due to phosphorus, namely, 486.4 pounds, it is found that on the plots receiving phosphorus alone the total average increase in the weight of crop per year has been 760.7 pounds.

Figure 7 shows graphically the percentage increases in the comparative total weights of seed, grain, straw, stalks and hay for the several treatments for the 30-year period.

Figure 8 shows graphically the percentage increases in the total weight of crops for the several treatments for 30 years.

Precipitation.—Plate I is a record of the monthly and annual precipitation from 1889-1937—a period of 49 years—at Brookings. See page 6.

Figure 9 shows graphically the annual precipitation at Brookings for the same period. The precipitation for the period covered in this report, 1908-1937, may be noted and the record of this period compared with the record of the preceding years. The average annual rainfall, including melted snow, is 19.657 inches, while the total for the 49 years is 80 ft.,

Fig. 9.—The Annual Precipitation at Brookings, S. D., 1889 to 1937

3.17 inches. Figure 10 shows graphically the average and monthly precipitation for the period 1889-1937.

A study of these data will reveal many interesting facts which need not be repeated in this discussion.

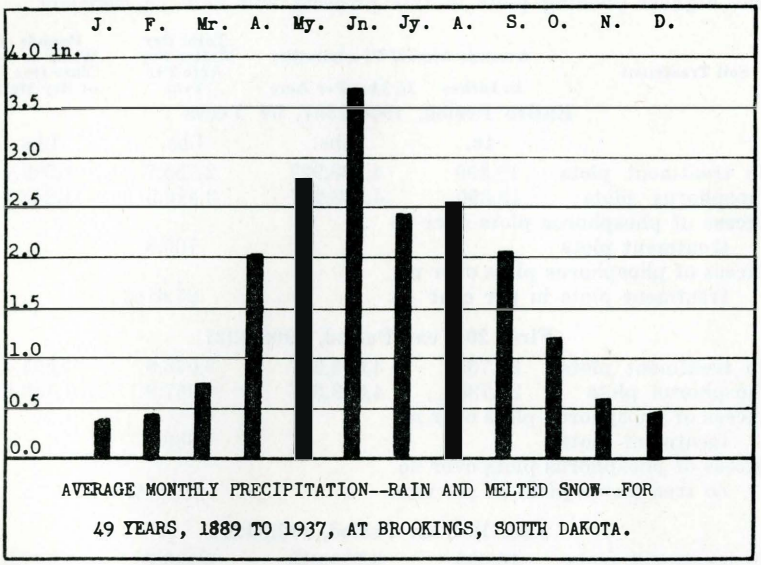

Fig. 10.—The Average Precipitation by Months at Brookings, S. D., 1889 to 1937

The statement is frequently made that rainfall is the controlling factor in crop production even in eastern South Dakota, but the data recorded in this bulletin indicate that during the 30 years, 1908-1937, the land receiving phosphorus has, with the same rainfall, produced 760.7 pounds more crop per acre per year than the land which received no phosphorus and that the lack of sufficient phosphorus in the soil under the climatic conditions which have prevailed has reduced the crop yield to that extent per acre per year below what it has been on soil receiving sufficient phosphorus.

For the period 1908 to 1937, during which this project has been in progress, the average precipitation in inches has been as follows:

Jan.	0.423	May	2.713	Sept.	2.098
Feb.	0.458	June	3.630	Oct.	1.137
Mar.	0.725	July	2.570	Nov.	0.663
April	1.971	Aug.	2.595	Dec.	0.423
Total	581.69		Average Annual		19.390

For the first 20-year period, 1909 to 1937, the average annual precipitation was 20.735 inches. For the last 10-year period the average an-

nual precipitation was 16.699 inches. One inch of precipitation over one acre weighs 226,350 pounds.

It is possible to compute the efficiency of the precipitation, as it has occurred, in the production of crops grown on soils receiving different fertility treatments. The comparison of the yields from the plots receiving no treatment and from those receiving phosphorus (the highest yielding plots in this project) will here be sufficient:

Soil Treatment	Average Annual Precipitation		Total Dry Matter Per Acre Per Year	Pounds of Water to Produce One Lb. of Dry Matter
	In Inches	In Lbs. Per Acre		
Entire Period, 1908-1937, 30 Years				
	In.	**Lbs.**	**Lbs.**	**Lbs.**
No treatment plots	19.390	4,338,927	2,755.7	1,592.7
Phosphorus plots	19.390	4,388,927	3,516.5	1,248.1
Excess of phosphorus plots over no treatment plots			760.8	
Excess of phosphorus plots over no treatment plots in per cent			27.61%	
First 20-Year Period, 1908-1927				
No treatment plots	20.735	4,693,367	3,078.8	1,524.4
Phosphorus plots	20.735	4,693,367	4,067.9	1,153.8
Excess of phosphorus plots over no treatment plots			989.1	
Excess of phosphorus plots over no no treatments plots in per cent			32.13%	
Last 10-Year Period, 1928-1937				
No treatment plots	16.699	3,779,818	2,126.7	1,777.3
Phosphorus plots	16.699	3,779,818	2,424.7	1,558.9
Excess of phosphorus plots over no treatment plots			298.0	
Excess of phosphorus plots over no treatment plots in per cent			14.01%	

Under the soil, slope and weather conditions which have prevailed during the existence of this project at Brookings the foregoing table reveals the following facts:

1. In all three of the periods of application of phosphorus to the the soil has increased the effectiveness of the rainfall.
2. An inch of rainfall during a period of scanty precipitation is is less effiective than an inch of rainfall during periods of more abundant precipitation, because when the annual precipitation was 16.699 inches one inch of rainfall produced on the phosphorus plots 145.2 pounds of dry matter; and when the annual precipitation was 20.735 inches one inch of rainfall produced 196.2 pounds on the same plots—an increase in effectiveness in producing crop of 35.12 per cent.
3. A fertile productive soil produces more crop with the same rainfall than a soil lacking in plant food.

A possible explanation for the advantage resulting from the application of phosphorus is that the growth of the crop during the growing

season when the rainfall is most abundant (See Figure 10) is not checked by a scarcity of phosphorus.

A possible explanation of the apparent increased water requirements of crops during periods of lower rainfall is that crops are stunted for lack of water during periods of drought and cannot resume normal growth even when rains do come. Light showers of rain, while they register in the rain gauge, may evaporate from the soil surface without coming in contact with the plant roots. High winds, high temperatures, and low relative humidity, often characteristic of dry seasons, also increase the evaporation from the leaves of plants.

Conclusions.—From a study of the foregoing data the following tentative conclusions may be drawn:

1. Phosphorus is the limiting plant food element in the soil under investigation.
2. Phosphorous when applied alone for 30 years has increased the total yield of all crops produced by 27.59 per cent, or 760.8 pounds per acre.
3. While the amount of rainfall is always an important factor in crop production, the application of phosphorous has apparently increased the efficiency of the average annual rainfall for the 30-year period by 27.59 per cent.
4. The application of nitrogen and potassium, either singly or in combination with the other fertilizing elements, has not produced on the whole as large yields as did the application of phosphorus alone.

CORN

TABLE 1.—Yields of Corn Following Certain Soil Treatments at Brookings, S. D. Rotations No. 25 and No. 27

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield		Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk	Grain	Stalk
Year.	Rot'n.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1910	(25)	51.30		55.80		58.50		45.10		47.00		54.00		53.20		55.10		55.80		47.10		48.47	
1910	(27)	44.20		53.60		58.60		44.70		46.00		59.10		49.10		55.80		58.70		43.60		44.60	
1915	(25)	14.10	1020	14.30	1000	14.30	1050	10.00	670	9.10	800	7.20	550	10.20	800	12.00	1050	10.60	920	9.00	750	10.73	857
1915	(27)	10.60	1150	9.80	1100	16.30	1750	12.80	1350	8.80	920	8.40	800	7.80	750	12.30	1370	16.60	1700	11.00	1150	10.13	1073
1920	(25)	45.60	1900	63.40	2300	66.90	2700	64.10	2300	56.00	2200	64.10	2450	60.40	2250	67.70	2750	58.40	3100	57.40	2600	53.00	2233
1920	(27)	61.40	2600	71.40	2550	67.40	2550	63.30	2450	65.10	2650	77.40	3250	69.00	2690	77.00	3000	84.70	3450	52.10	2625	59.53	2625
1925	(25)	24.40	950	24.00	1100	24.60	1200	25.10	1300	24.00	1000	22.60	1250	23.40	1150	21.10	1200	22.00	1250	21.10	950	23.17	967
1925	(27)	23.00	950	27.00	1050	26.40	1150	25.70	1050	25.40	1150	28.00	1250	26.40	1200	24.70	1250	25.70	1300	24.10	1050	24.17	1050
1930	(25)	14.29	2360	14.43	2610	13.29	2190	11.71	2280	12.57	2220	11.71	2180	14.43	2410	7.43	2380	9.00	2450	11.71	2160	12.86	2247
1930	(27)	16.86	2100	18.14	2170	13.29	2570	13.71	2560	17.43	2300	17.14	2600	18.14	2830	10.00	2900	13.14	3080	18.28	2220	17.52	2207
1935	(25)	21.76	1927	22.47	2377	24.56	2231	23.68	2142	26.08	2174	23.44	1809	31.17	2018	22.40	2782	18.48	2006	20.48	2516	22.77	2206
1935	(27)	18.33	3027	21.60	2378	23.04	2707	25.60	2848	25.76	2757	25.84	3201	23.44	2569	21.20	3326	24.31	2808	25.57	3694	23.22	3159
Av.	(25)	28.58	1631	32.40	1565	32.01	1874	29.95	1738	29.13	1679	30.51	1648	32.13	1726	30.96	2032	29.05	1945	27.80	1795	28.50	1702
Av.	(27)	29.07	1965	33.59	1850	34.17	2145	30.97	2052	31.42	1955	35.98	2220	32.31	1990	33.50	2369	37.19	2468	29.11	2148	29.86	2023
Av. 25 & 27		28.82	1798	33.00	1864	33.93	2010	30.46	1895	30.27	1817	33.24	1934	32.22	1858	32.23	2201	33.12	2206	28.45	1972	29.18	1862
Increase over "Av. of None"				3.82	2	4.75	148	1.28	33			4.06	72	3.04	−4	3.05	339	3.94	344				
Increase per cent				13.09	0.11	16.28	7.95	4.39	1.77			13.91	3.87	10.42	−0.21	10.45	18.21	13.50	18.47				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

WHEAT

TABLE 2.—Yields of Wheat Following Certain Soil Treatments at Brookings, S. D. Rotations No. 25 and No. 27

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year.	Rot'n.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1908	25	12.80	3510	14.10	3150	15.10	2380	13.50	2460	12.20	2760	16.30	3070	16.00	3090	15.50	2820	16.00	2990	12.50	2530	12.50	2933
1911	27	5.50	870	6.50	910	5.20	740	5.80	700	6.00	690	5.20	740	6.00	790	5.00	600	4.70	720	6.00	740	5.83	767
1912	25	18.50	1840	19.10	1990	23.00	2170	15.00	1310	12.80	1150	21.80	2150	21.10	1990	22.50	2120	25.80	2390	13.00	1250	14.77	1413
1916	27	11.20	2110	11.80	2790	13.20	3210	10.70	2140	9.80	2040	11.80	3300	10.70	2710	11.80	3130	11.30	2550	9.00	2310	10.00	2153
1917	25	34.00	3240	32.00	3630	37.70	3740	29.70	3020	27.80	2850	33.50	3940	30.80	3430	36.70	3600	34.70	3920	29.20	2830	30.33	2973
1921	27	10.83	1120	12.33	1510	18.33	2450	13.16	1670	10.83	1290	17.33	2270	12.33	1530	16.66	1760	16.00	1980	13.33	1550	11.66	1320
1922	25	16.50	1880	16.50	2870	20.16	1590	15.00	1600	12.00	1680	16.83	2760	11.83	2830	16.83	1390	16.00	2380	16.00	1850	14.83	1803
1926	27	12.33	2960	19.25	3145	17.33	3360	10.50	3370	12.84	2770	15.00	3900	12.33	3560	11.17	3330	10.33	3960	8.50	3190	11.22	2973
1927	25	17.30	1530	17.80	1230	23.50	1390	18.80	1270	20.80	1170	21.30	1950	20.70	2720	23.80	1500	18.90	1225	20.00	1900	19.37	1533
1931	27	11.67	1400	10.83	1750	15.17	1490	12.50	1550	12.67	1480	14.83	1460	14.33	1740	14.50	1830	14.83	1910	15.00	1600	13.11	1493
1932	25	12.83	1970	11.67	1980	15.67	2540	13.67	1520	11.33	2040	14.67	2540	13.17	2030	16.67	2600	14.17	2550	12.50	1850	12.22	1953
1936	27	8.00	1820	7.83	1930	11.17	2630	10.00	1800	7.33	1460	8.50	2090	7.33	1460	11.33	1920	10.00	2600	9.33	2040	8.22	1773
1937	25	20.66	2260	16.57	1650	15.50	970	14.83	840	10.70	1170	11.83	1790	10.50	1370	12.33	1060	9.67	1220	9.83	1660	13.66	1697
Av.	25	18.94	2319	18.26	2357	21.52	2111	17.14	1717	15.35	1831	19.46	2600	17.59	2497	20.62	2156	19.32	2382	16.15	1981	16.81	2044
Av.	27	9.92	1713	11.42	2006	13.40	2313	10.44	1872	9.91	1622	12.11	2293	10.50	1965	11.74	2095	11.19	2287	10.19	1905	10.01	1746
Av. 25 & 27		14.78	2039	15.11	2195	17.77	2205	14.05	1788	12.84	1735	15.61	2458	14.39	2250	16.52	2128	15.57	2338	13.40	1946	13.67	1906
Increase over "Av. of None"				1.44	289	4.10	299	0.38	−118			1.94	552	0.72	344	2.85	222	1.90	432				
Increase per cent				10.53	15.16	29.99	15.69	2.78	−6.19			14.19	28.96	5.27	18.05	20.85	11.65	13.90	22.67				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

OATS

TABLE 3.—Yields of Oats Following Certain Soil Treatments at Brookings, S. D. Rotations No. 25 and No. 27

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year.	Rot'n.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1909	27	31.60	2440	30.60	2870	35.00	2730	31.20	2650	29.10	2420	30.60	2770	31.20	2600	34.40	2850	31.60	2690	30.00	2690	30.27	2517
1911	25	3.30	1045	2.80	910	2.20	930	2.40	825	2.80	1010	1.40	1105	2.00	1085	1.70	1045	1.60	900	1.90	891	2.67	982
1913	27	33.70	680	35.00	970	49.70	970	35.90	660	35.90	650	45.30	1270	34.70	910	49.40	950	45.00	1150	32.50	670	34.03	667
1916	25	63.40	1670	69.70	2220	66.90	2490	60.60	1410	59.70	1640	51.60	2080	62.20	2110	58.40	2250	49.10	1930	65.30	1810	62.80	1707
1918	27	34.10	1050	36.60	1440	44.70	1500	31.90	1060	32.50	820	49.10	1670	32.80	950	59.70	1330	39.10	1600	37.50	1050	34.70	973
1921	25	32.50	790	32.18	800	60.00	800	30.93	820	26.87	765	35.62	1330	31.87	1080	40.62	440	46.25	1380	35.62	1010	31.67	855
1923	27	56.56	1560	53.43	2150	70.93	2040	62.18	1740	61.56	1730	64.65	1560	58.12	2370	67.18	1950	45.93	2010	61.56	1780	59.89	1690
1926	25	15.62	2220	17.50	1660	21.89	2460	15.62	2200	19.37	2100	37.50	1700	22.50	2420	24.37	2520	26.25	2760	25.94	1970	20.30	2097
1928	27	19.06	950	16.88	1600	32.81	1350	30.94	910	11.88	1160	4.69	1010	3.13	1300	10.00	720	7.19	1350	16.25	700	15.73	937
1931	25	21.25	940	20.63	1190	18.75	1550	19.38	1330	16.25	1340	12.50	1800	16.88	1660	15.00	1770	10.63	1810	14.38	1240	17.29	1173
1933	27	0.63	380	1.88	440	2.19	330	0.94	370	0.63	180	4.06	570	1.88	340	2.81	510	5.31	580	3.13	660	1.46	403
1936	25	21.25	1020	23.13	1160	23.13	1410	22.81	1020	19.38	780	20.63	1540	24.06	1430	26.25	1260	19.69	1670	25.31	990	21.98	930
Av.	25	26.22	1281	27.66	1323	32.15	1607	25.29	1268	24.06	1273	26.54	1593	26.59	1631	27.72	1548	25.59	1742	28.08	1319	26.12	1291
Av.	27	29.28	1177	29.07	1578	39.22	1487	32.18	1232	28.60	1160	33.06	1475	26.97	1412	32.25	1385	29.02	1597	30.16	1257	29.35	1198
Av. 25 & 27		27.75	1229	28.36	1451	35.68	1547	28.73	1250	26.33	1216	29.80	1534	26.78	1521	30.82	1491	27.30	1669	29.12	1288	27.73	1244
Increase over "Av. of None"				0.63	207	7.95	303	1.00	6			2.07	290	−0.95	277	3.09	247	−0.43	425				
Increase per cent				2.27	16.64	28.67	24.36	3.61	0.48			7.46	23.31	−3.43	22.27	11.14	19.86	−1.55	34.16				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

BARLEY

TABLE 4.—Yields of Barley Following Certain Soil Treatments at Brookings, S. D. Rotations No. 25 and No. 27

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year.	Rot'n.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1908	27	35.70	1910	47.20	3030	46.50	3110	30.60	1780	28.70	1770	43.30	2770	32.20	2690	40.60	1350	43.30	3420	29.50	1640	31.30	1773
1909	25	20.88	2550	24.20	2540	29.80	2620	22.50	2520	22.70	2460	26.70	2670	26.00	2759	31.50	2690	32.10	2660	27.70	2470	23.76	2493
1912	27	38.70	1470	48.90	2150	52.00	1980	37.90	1760	35.20	1540	55.80	2260	41.60	1850	49.30	2060	52.50	2620	37.90	1720	37.27	1577
1913	25	14.20	750	15.10	1135	17.90	1090	13.80	1000	12.70	1050	21.90	1640	16.50	1520	21.50	1550	29.90	2040	12.90	1060	13.27	953
1917	27	45.80	1950	52.30	2640	62.90	2340	50.00	2150	47.70	2010	51.30	2400	54.00	2560	62.30	2180	57.10	2520	51.00	2010	48.17	1990
1918	25	22.50	1220	14.20	1170	17.70	1350	8.50	860	10.00	880	6.00	1500	7.50	1020	8.50	1390	5.60	1460	10.40	910	14.30	1003
1922	27	22.50	930	31.45	1410	40.41	1490	26.66	1010	21.08	890	46.25	2030	23.75	1300	31.25	1270	38.95	1890	28.33	940	23.97	920
1923	25	33.54	1670	38.12	2470	41.04	2080	36.66	1750	35.42	1760	32.08	2010	38.96	2160	43.04	2060	35.41	2050	36.25	1980	35.07	1803
1927	27	35.41	1080	39.58	1510	43.75	1580	40.00	1050	34.37	1330	50.62	1570	39.79	1600	47.50	1450	53.75	1920	42.08	1190	37.29	1200
1928	25	25.00	1200	25.83	1760	28.75	820	16.67	1220	19.17	1300	15.00	1380	8.75	1680	14.17	1120	17.50	1660	13.96	1030	19.38	1177
1932	27	30.21	1910	32.50	2550	44.17	2520	37.92	2080	31.67	2180	43.75	2420	40.00	2340	47.08	2420	44.79	2610	40.00	2320	33.96	2137
1933	25	0.10	155	0.10	135	0.10	145	0.06	87	0.10	55	0.05	98	0.17	412	0.10	255	0.03	149	0.10	195	0.10	135
1937	27	21.04	1440	31.25	2300	41.67	2250	34.79	1830	24.58	1620	35.42	1900	29.79	1620	32.50	1490	37.71	2390	29.17	1400	24.93	1487
Av.	25	19.37	1258	19.59	1535	22.55	1351	16.37	1240	16.68	1251	16.96	1550	16.31	1592	19.80	1511	20.09	1670	16.89	1274	17.65	1261
Av.	27	32.77	1527	40.45	2223	47.34	2181	36.84	1666	31.90	1620	46.63	2193	37.30	1994	44.36	1746	46.87	2481	36.85	1603	33.84	1583
Av. 25 & 27		26.58	1403	30.83	1908	35.90	1798	27.39	1469	24.88	1450	32.94	1896	27.62	1809	33.03	1637	34.51	2107	27.64	1451	26.37	1434
Increase over "Av. of None"				4.46	474	9.53	364	1.02	35			6.57	462	1.25	375	6.66	203	8.14	673				
Increase per cent				16.91	33.05	36.14	25.38	3.87	2.44			24.91	32.22	4.74	26.15	25.26	14.16	30.89	46.93				

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

RED CLOVER

TABLE 5.—Yields of Red Clover Seed and Straw, Following Certain Soil Treatments at Brookings, S. D. Rotations No. 25 and No. 27

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield		Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Year.	Rot'n.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1914	25	70	760	85	1115	90	880	80	870	100	915	90	970	115	1065	100	765	130	1100	90	895	86.7	857
1914	27	110	1325	150	1410	170	1660	140	1370	120	1165	140	1725	130	1570	120	1540	140	2030	90	1300	106.7	1263
1919	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	25	50	950	115	1585	200	2400	95	1605	130	1520	115	2265	130	2570	130	2970	100	2200	85	1595	88.3	1855
1924	27	55	1365	85	1635	165	2415	90	1710	95	1305	125	2875	145	1955	200	2440	140	2560	90	1410	80.0	1360
1929	25	15	1085	23	3278	11	1289	10	1190	11	1189	1*	19	3*	13	28	1673	4*	16	15	1785	14.0	1353
1929	27	24	1576	5*	75	35	1565	35	1495	28	1375	4*	16	3*	13	30	1770	1*	199	20	1480	24.0	1477
1934	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Av.	25	27	559	45	1196	60	914	37	733	48	725	41	651	50	730	52	1082	47	663	38	855	38.0	713
Av.	27	38	853	48	624	74	1128	53	915	49	769	54	923	56	708	70	1150	56	958	40	838	42.1	820
Av. 25 & 27		32	706	46	910	67	1021	45	824	48	747	48	787	53	719	61	1116	52	811	39	847	40.0	767
Increase over "Av. of None"				6	143	27	254	5	57			8	−20	13	−48	21	349	12	44				
Increase per cent				15.00	18.64	67.50	33.12	12.50	7.43			20.00	2.61	32.50	−6.26	52.50	45.50	30.00	5.74				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

* These plots not mowed. Clover plants hand-picked. Weights are of the plants picked. Very high percentage of weeds on these plots. Owing to weather conditions in 1919, no seed formed and both cuttings of the clover crop were used for hay. In 1934 clover crop failed on account of drought.

All plots seeded to Bison flax which also failed completely on account of drought.

SUMMARY

TABLE 7.—Summary of the Results From All Treatments on All Crops—Corn, Wheat, Oats, Barley, Red Clover—in Rotations No. 25 and No. 27 at Brookings, S. D., Expressed as Weighted Averages

Crop	Corn-Grain		Corn-Stalks		Wheat-Grain		Wheat-Straw		Oats-Grain		Oats-Straw		Barley-Grain		Barley-Straw		Clov.-Seed		Clov.-Straw		Clov.-Hay	
No. of Yrs.	6		5		13		13		12		12		13		13		5		5		5	
Treatment	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.
None	29.18		1862		13.67		1906		27.73		1244		26.37		1434		40		767		1461	
N	33.00	3.82	1864	**2**	15.11	1.44	2195	289	28.36	**0.63**	1451	207	30.83	4.46	1908	474	46	6	910	143	1323	−138
P	33.93	4.75	2010	148	17.77	**4.10**	2205	299	35.68	**7.95**	1547	303	35.90	**9.53**	1798	364	67	**27**	1021	254	2655	**1194**
K	30.46	1.28	1895	33	14.05	0.38	1788	−118	28.73	1.00	1250	**6**	27.39	1.02	1469	35	45	5	824	57	1479	18
NP	33.24	4.06	1934	72	15.61	1.94	2458	**552**	29.80	2.07	1534	290	32.94	6.57	1896	462	48	8	787	20	1457	−4
NK	32.22	3.04	1858	−4	14.39	0.72	2250	344	26.78	−0.95	1521	277	27.62	1.25	1809	375	53	13	719	−48	1130	−331
PK	32.23	3.05	2201	339	16.52	2.85	2128	222	30.82	3.09	1491	247	33.03	6.66	1637	203	61	21	1116	**349**	2294	833
NPK	33.12	3.94	2206	**344**	15.57	1.90	2338	432	27.30	−0.43	1669	**425**	34.51	8.14	2107	673	52	12	811	44	1584	123

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment.

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
N	13.09	0.11	10.53	15.16	2.27	16.64	16.91	33.05	15.00	18.64	−9.45
P	**16.28**	7.95	**29.99**	15.69	**28.67**	**24.86**	**36.14**	25.38	**67.50**	33.12	**81.72**
K	4.39	1.77	2.78	−6.19	3.61	0.48	3.87	2.44	12.50	7.43	1.23
NP	13.91	3.87	14.19	**28.96**	7.46	23.31	24.91	32.22	20.00	2.62	−0.27
NK	10.42	−0.21	5.27	18.05	−3.43	22.27	4.74	26.15	32.50	−6.26	−22.66
PK	10.45	18.21	20.85	11.65	11.14	19.86	25.26	14.16	52.50	**45.50**	57.02
NPK	13.50	18.47	13.90	22.67	−1.55	**34.16**	30.89	**46.93**	30.00	5.74	8.42

NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment. The figures indicating the greatest increase in yield in each crop are printed in bold face type. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

RED CLOVER

TABLE 6.—Yields of Red Clover Hay Following Certain Soil Treatments at Brookings, S. D., Rotations No. 25 and No. 27

Treatment			None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot. No.			140 or 150		141 or 151		142 or 152		143 or 153		144 or 154		145 or 155		146 or 156		147 or 157		148 or 158		149 or 159			
Yield			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Year.	Rot.	Cut.	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total	Cut.	Total
1914	25	1st	1330	1330	1580	1580	3280	3280	1700	1700	1890	1890	2780	2780	1810	1810	3590	3590	3200	3200	2120	2120	1780	1780
1914	27	1st	1720	1720	1580	1580	2820	2820	1760	1760	1700	1700	2820	2820	1570	1570	3170	3170	2420	2420	1500	1500	1640	1640
1919	25	1st	2140		1630		2890		1680		1770		1130		1380		1870		1290		1490		1800	
1919	25	2nd	3050	5190	2950	4580	3650	6540	2400	4080	2300	4070	3150	4280	2400	3780	3250	5120	2850	4140	2450	3940	2600	4400
1919	27	1st	1310		1100		3310		970		1140		470		390		1140		590		1000		1150	
1919	27	2nd	2400	3710	2600	3700	3700	7010	1950	2920	2700	3840	2600	3070	1800	2190	3000	4140	2550	3140	2550	3550	2550	3700
1924	25	1st	1100	1100	800	800	2490	2490	1240	1240	1100	1100	750	750	850	850	2710	2710	640	640	900	900	1033	1033
1924	27	1st	900	900	990	990	2730	2730	1610	1610	1640	1640	870	870	1100	1100	3430	3430	2300	2300	1190	1190	1243	1243
1929	25	1st	800	800	0	0	625	625	625	625	550	550	0	0	0	0	575	575	0	0	400	400	583	583
1929	27	1st	325	325	0	0	1050	1050	850	850	100	100	0	0	0	0	200	200	0	0	275	275	233	233
1934	25	1st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	27	1st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Av.	25	1st	1074		802		1857		1049		1062		932		808		1749		1026		982		1039	
Av.	27	1st	851		734		1982		1038		916		832		612		1588		1062		798		853	
Av.25 & 27		1st	963		768		1920		1044		989		882		710		1669		1044		888		946	
Av.	25	2nd	3050		2950		3650		2400		2300		3150		2400		3250		2850		2450		2600	
Av.	27	2nd	2400		2600		3700		1950		2700		2600		1800		3000		2550		2550		2550	
Av.25 & 27		2nd	2725		2775		3675		2175		2500		2875		2100		3125		2700		2500		2575	
Av.	25	Total		1684		1392		2587		1529		1522		1562		1288		2399		1596		1472		1559
Av.	27	Total		1331		1254		2722		1428		1456		1352		972		2188		1572		1303		1363
Av.25 & 27		Total		1508		1323		2655		1479		1489		1457		1130		2294		1584		1388		1461
Increase (total) over "Av. of None"						-138		1194		18				-4		-331		833		123				
Increase per cent						-9.45		81.72		1.23				-0.27		-22.66		57.02		8.42				

NOTE.—The minus (-) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

Owing to the heavy rainfall during the summer of 1919, no seed formed and both cuttings were used for hay.

In 1934 clover crop failed on account of drought. Seeded to Bison flax which was also a complete failure on account of drought.

GENERAL SUMMARY

TABLE 8.—General Summary of the Results From All Treatments on All Crops: Corn, Wheat, Oats, Barley, Red Clover, in Rotations No. 25 and No. 27 Expressed in Terms of the Total Amounts of Dry Matter Produced Per Acre for 30 Years

Treatment Crop	No. Acre Yrs.	None Grain Lbs.	N Grain Lbs.	P Grain Lbs.	K Grain Lbs.	NP Grain Lbs.	NK Grain Lbs.	PK Grain Lbs.	NPK Grain Lbs.
Corn	12	24,512	27,720	28,502	25,586	27,922	27,064	27,074	27,820
Wheat	13	10,663	11,786	13,861	10,959	12,176	11,224	12,886	12,145
Oats	12	10,648	10,890	13,701	11,032	11,443	10,284	11,835	10,483
Barley	13	16,455	19,238	22,402	17,091	20,555	17,235	20,611	21,534
Cl. Seed	10	400	460	670	450	480	530	610	520
Total	(60)	62,678	70,094	79,136	65,118	72,576	66,337	73,016	72,502
Total Gain		____	7,416	16,458	2,440	9,898	3,659	10,338	9,824
Av. Gain per Year		____	123.6	274.3	40.7	165.0	61.0	172.3	163.7
Gain Per Cent		____	11.83	26.26	3.90	15.80	5.84	16.49	15.67
		Straw, Stalks and Hay	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**	**Straw, Stalks and Hay**
Corn	10	18,620	18,640	20,100	18,950	19,340	18,580	20,010	22,060
Wheat	13	24,778	28,535	28,665	23,244	31,954	29,250	27,664	30,394
Oats	12	14,928	17,412	18,564	15,000	18,408	18,252	17,892	20,028
Barley	13	18,642	24,804	23,374	19,097	24,648	23,517	21,281	27,391
Cl. Straw	10	7,670	9,100	10,210	8,240	7,870	7,190	11,160	8,110
Cl. Hay	10	14,610	13,230	26,550	14,790	14,570	11,300	22,940	15,840
Total	(58)	99,248	111,721	127,463	99,321	116,790	108,089	122,947	123,823
Total Gain		____	12,473	28,215	73	17,542	8,841	23,699	24,575
Av. Gain per Year		____	215.0	486.4	1.3	302.4	152.4	408.6	423.7
Gain Per Cent		____	12.57	28.43	0.08	17.67	8.91	23.88	24.76
		Total Amount of Dry Matter Produced Under the Several Treatments							
		Grain, Straw, Stalks and Hay	**Grain, Straw, Stalks and Hay**	**Grain, Straw, Stalks and Hay**	**Grain, Straw, Stalks and Hay**	**Grain, Straw, Stalks and Hay**	**Grain, Straw, Stalks and Hay**	**Grain Straw, Stalks and Hay**	**Grain, Straw, Stalks and Hay**
Corn		43,132	46,360	48,602	44,536	47,262	45,644	49,084	49,880
Wheat		35,441	40,321	42,526	34,203	44,130	40,474	40,550	42,539
Oats		25,576	28,302	32,265	26,032	29,851	28,536	29,727	30,511
Barley		35,097	44,042	45,776	36,188	45,203	40,752	41,892	48,925
Clover		22,680	22,790	37,430	23,480	22,920	19,020	34,710	24,470
Total		161,926	181,815	206,599	164,439	189,366	174,426	195,963	196,325
Total Gain		____	19,889	44,673	2,513	27,440	12,500	34,037	34,399
Average Gain per Year		____	338.6	760.7	42.0	467.4	213.4	580.9	587.4
Gain Per Cent		____	12.28	27.59	1.55	16.95	7.72	21.02	21.24

General Summary of the Increases in Yield for the Several Treatments Over No Treatments for All Crops Grown

Total Gain Grain 30 Years	7,416	16,458	2,440	9,898	3,659	10,338	9,824
Total Gain Straw, Etc., 29 Years	12,473	28,215	73	17,542	8,841	23,699	24,575
Total Gain Dry Matter	19,889	44,673	2,513	27,440	12,500	34,037	34,399
Gain Per Cent Grain 30 Years	11.83	26.26	3.90	15.80	5.84	16.49	15.67
Gain Per Cent Straw, Etc., 29 Years	12.57	28.43	0.08	17.67	8.91	23.88	24.76
Gain Per Cent Total Dry Matter	12.28	27.59	1.55	16.95	7.72	21.02	21.24

* Owing to the succession of crops in rotations 25 and 27, corn and clover were grown on both acres the same years. The average yields per acre per year for None (No Treatment) for all crops were: Grain, 1044.6 lbs.; straw, etc., 1711 lbs.; total 2755.6 lbs.

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

Section II. Manure, Phosphate and Limestone Test, At Brookings, S. D.

Introduction.—The results here reported have been obtained from investigations carried on under an experiment station project supported by allotments from Hatch funds. This fund is from appropriations by the Congress of the United States as authorized by the Hatch act. The allotment of funds for the project is made by the director of the experiment station.

History.—The project was begun in 1912 and has been continued without interruption. The results for the 25 years ending in 1937 are summarized in this report.

Object.—The purpose of this project is to determine, as indicated by crop yield:

1. The relative effectiveness of acid phosphate and rock phosphate when applied with manure.
2. The effect of limestone when applied alone, with manure, with manure and acid phosphate, and with manure and rock phosphate.

Plan of the Work.—The project is located on four acres of land situated on the "East Farm" at Brookings, S. D.

Figure 11 shows the plan of the plots, their numbers, and soil treatment applied. Each plot is two rods wide and eight rods long. The area is 16 square rods or one-tenth of an acre. The plots in each acre are separated by an alley 40 inches wide and which for most of the years have been kept clear of weeds by cultivation. More recently the whole acre, plots and alleys, have been planted and at harvest time the crop in the alleys has been removed before harvesting the crop from the plots.

Soil.—The soil on the plots involved in this project is weathered from the glacial till deposited by the Kansan ice sheet. Although the surface layer has no doubt been somewhat modified by the action of the wind the material is not strictly loessial. The soil type is Barnes sandy loam.

The soil profile is that of tschernozem, or dark colored soil, of the regions of limited rainfall, such as the Great Plains of America and similar climatic areas in the U.S.S.R. (Russia.)

The surface or "A" horizon extends to a depth of about 14 inches and consists of a very dark grayish brown sandy loam. At the lower limit of this horizon, or layer, pebbles and even boulders, sometimes of large size, are found in the grayish yellow weathered till which also contains a considerable amount of silt and clay mixed with the pebbles and sand. The pebbles and boulders do not predominate, but are noticeable when taking soil samples with an auger.

Below 14 inches and varying somewhat in depth there is a definite calcium carbonate, "lime," accumulation which is characteristic of the "B" horizon of soils of this group. The soil belongs definitely in the great group of soils now coming to be known as pedocals or calcium carbonate accumulating soils. These soils must be considered as definitely distinguished from the soils of regions having heavier rainfall where all calcium carbonate is removed from the soil profile by percolating water. In the region of dark colored, calcium carbonate

O	240	O	340	O	440	O	540
M	241	M	341	M	441	M	541
MAP	242	MAP	342	MAP	442	MAP	542
MRP	243	MRP	343	MRP	443	MRP	543
O	244	O	344	O	444	O	544
L	245	L	345	L	445	L	545
LM	246	LM	346	LM	446	LM	546
LMAP	247	LMAP	347	LMAP	447	LMAP	547
LMRP	248	LMRP	348	LMRP	448	LMRP	548
O	249	O	349	O	449	O	549

ROTATION NO. 1.

CORN-OATS-WHEAT-LEGUME: MANURE, PHOSPHATE, AND LIMESTONE TEST.

EXPERIMENT STATION, BROOKINGS, S.DAK.

Fig. 11.—Plan of the Plots Utilized in the Manure, Phosphate, Limestone Investigations at Brookings, S. D.

The letters indicate the kinds of fertilizers applied to the several plots:

O means no treatment applied.

M means manure applied at the rate of 10 tons per acre for every four years.

AP means phosphorus applied in the form of acid phosphate at the rate of 300 pounds per acre once in four years.

RP means phosphorus in the form of rock phosphate applied at the rate of 600 pounds per acre once in four years.

L means limestone applied at the rate of one ton per acre once in four years.

Each symbol has the same meaning whether it occurs alone or in combination with others. The meaning is the same throughout the report on this project.

accumulating soils the removal of soluable material from the soil profile by percolating water is negligible.

Soil Preparation and Application of Plant Food.—In Rotation No. 1 the soil is fall plowed seven inches deep for corn. After the corn crop a disk is used in the spring to prepare the corn stubble for oats. After the oats crop is removed the soil is plowed five inches deep in preparation for winter wheat which is seeded the same year. Red clover or sweet clover, as the case may be, is broadcast as a catch crop in the winter wheat the following spring. Sweet clover or red clover, being biennials, make some growth in the wheat, but the crop of hay and seed is harvested the following year, after which the soil is again fall plowed seven inches deep for corn which succeeds the legume crop the following year. When it has been necessary to substitute soy beans as a legume crop when clover fails, the soil was plowed in preparation for the soy beans.

Manure is applied before fall plowing for corn at the rate of 10 tons per acre and the acid phosphate, 300 pounds per acre, and rock phosphate, 600 pounds per acre, are broadcast at the same time and then plowed under with the manure. Limestone is applied broadcast

at the rate of one ton per acre before plowing the oats stubble for wheat.

At the beginning of the project in 1913, 300 pounds of acid phosphate containing about 7 per cent phosphorus, approximately 21 pounds, cost about the same as 600 pounds of rock phosphate containing 12½ per cent phosphorus, or 75 pounds. Prices have, of course, changed somewhat since that time.

Crops Grown.—The sequence of crops grown in this project is called Rotation No. 1 in the experiment station records and consists of corn, followed by oats, followed by winter wheat, followed by a legume crop. The legume crop is regularly sown in the winter wheat in the spring.

The varieties of crops grown have been:

Corn: Brookings 86 except 1925. All Dakota 1925.

Oats: Swedish Select 1914, 1915; Sixty-Day 1916-1937.

Wheat: Red Fife 1914; Turkey 144, 1915-16; Kubanka 75, 1917; Acme 284, 1918; Turkey 144, 1919-1935; Thatcher, 1936; Turkey 144, 1937. Spring wheats were substituted after 1915 when winter wheat failed.

Legume: Red Clover 1913-1919; Sweet Clover 1920-1930; Soy Beans 1931; Sweet Clover 1932; Red Clover 1933-1934; Soy Beans 1935-1936; Red Clover 1937. Soy Beans were substituted when clovers failed.

The project began in 1912 with the planting of corn on plots 540-549. In 1913 corn was planted on plots 440-449 and oats seeded on plots 540-549. In 1914 corn was grown on plots 340-349, oats on plots 440-449, wheat on plots 540-549. In 1915 corn was planted on plots 240-249, oats on plots 340-349, wheat on plots 440-449, and red clover on plots 540-549. In 1916 corn was grown on plots 540-549, and the rotation of crops was repeated as before. Since 1912 corn has been grown 25 years, oats 24 years, wheat 23 years, and legumes 22 years.

Yields.—In the following tables the yields of the several crops for each year grown and the average yields of each crop and of all crops for all the years grown are recorded.

Corn.—From Table No. 9 it is observed that for the 25 years corn was grown the average yields per acre following the several treatments were as follows:

	Yield bu.	Increase over no treatment	Increase per cent
No treatment	34.98		
Manure only	38.51	3.53	10.09
Manure and acid phosphate	39.20	4.22	12.06
Manure and rock phosphate	39.19	4.21	12.04
Limestone alone	36.24	1.26	3.60
Limestone and manure	38.28	3.30	9.43
Limestone, manure, and acid phosphate	36.94	1.96	5.60
Limestone, manure, and rock phosphate	37.27	2.29	6.55

The application of acid phosphate with manure increased the yield of corn 0.69 bu. over the yield following the application of manure alone, while rock phosphate increased the yield 0.68 bu. While the application of limestone alone indicates an average increase in yield of

1.26 bu., it has, when applied with manure, or manure and phosphate, apparently reduced the yields following these treatments without limestone.

The yields of corn stalks, or stover, are also recorded in Table 9 and the comparative yields of grain and stalks in per cent are shown graphically in Figure 12.

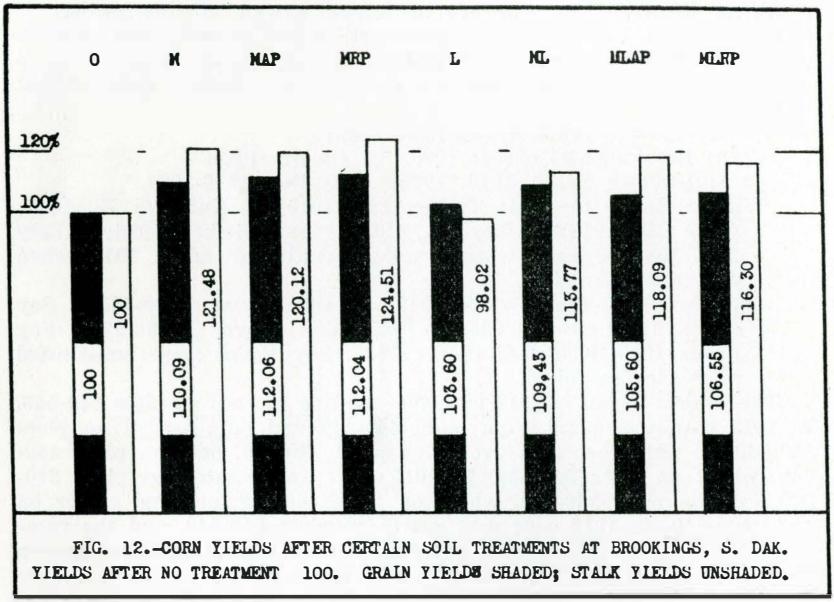

FIG. 12.—CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

Oats.—From Table No. 10 it is observed that for the 24 years oats was grown the average yields per acre following the several treatments were as follows:

	Yield bu.	Increase over no treatment	Increase per cent
No treatment	46.27		
Manure only	49.87	3.60	7.78
Manure and acid phosphate	50.53	4.26	9.21
Manure and rock phosphate	52.03	5.76	12.45
Limestone only	48.33	2.06	4.45
Limestone and manure	52.08	5.81	12.56
Limestone, manure, and acid phosphate	53.22	6.95	15.02
Limestone, manure, and rock phosphate	53.26	6.99	15.11

The application of acid phosphate with manure increased the yield of oats over that following the application of manure alone 0.66 bu., and rock phosphate 2.16 bu. over manure alone.

Limestone alone increased the yield of oats 2.06 bu. over the yield following no treatment and when applied with manure it increased the yield over that following manure 2.21 bu.; over manure and acid phos-

phate 2.69 bu.; and over manure and rock phosphate 1.23 bu. when added to these treatments.

The yields of oats straw following the several treatments are also recorded in Table No. 10 and the comparative yields of grain and straw in per cent are shown graphically in Figure 13.

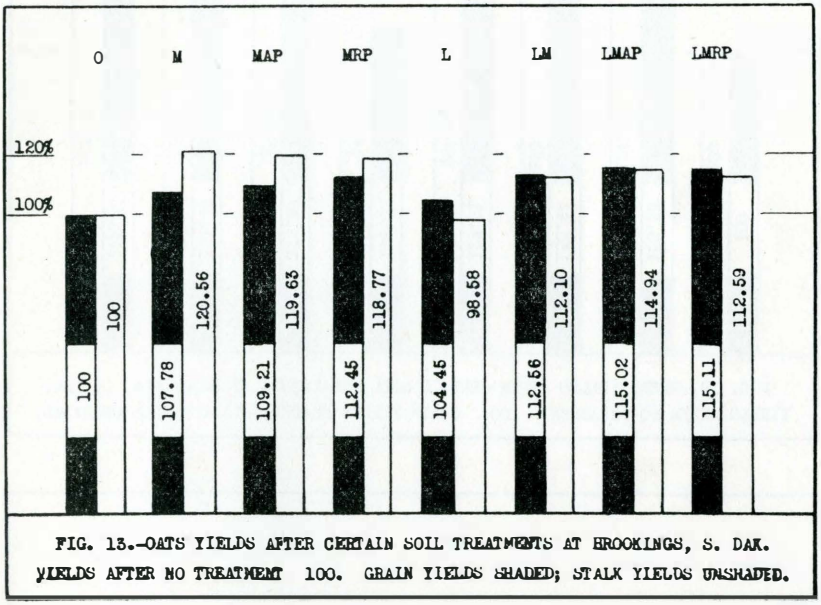

FIG. 13.-OATS YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

Wheat.—From Table No. 11 it is observed that for the 23 years wheat was grown the average yields per acre following the several treatments were as follows:

	Yield bu.	Increase over no treatment bu.	Increase per cent
No treatment	14.10		
Manure	17.39	3.29	23.33
Manure and acid phosphate	18.40	4.32	30.64
Manure and rock phosphate	17.33	3.23	22.91
Limestone alone	15.23	1.13	8.01
Limestone and manure	18.10	4.00	28.37
Limestone, manure, and acid phosphate	18.54	4.44	31.49
Limestone, manure, and rock phosphate	17.28	3.18	22.55

Limestone alone increased the yield of wheat 1.13 bu. and when applied with manure increased the yield over that following manure alone 0.71 bu.; over manure and acid phosphate 0.12 bu.; and decreased the yield following manure and rock phosphate 0.05 bu.

The yields of wheat straw following the several treatments are also recorded in Table No. 11 and the comparative yields of grain and straw in per cent are shown graphically in Figure 14.

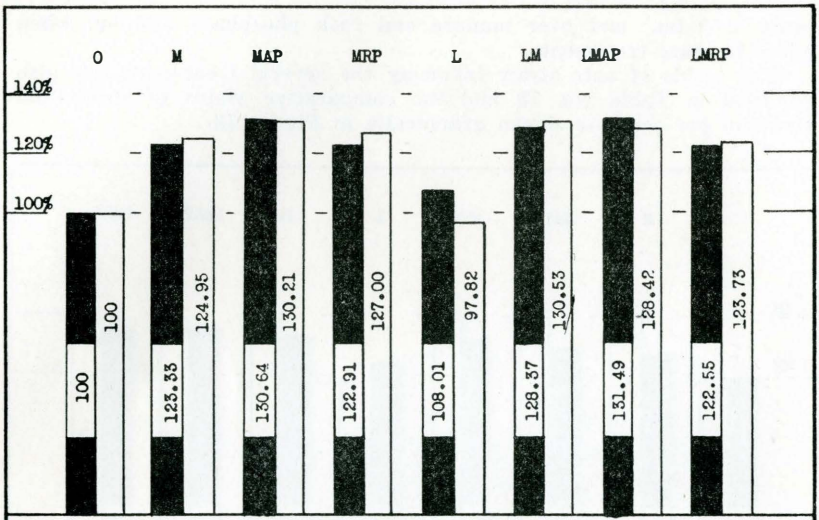

FIG. 14.-WHEAT YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

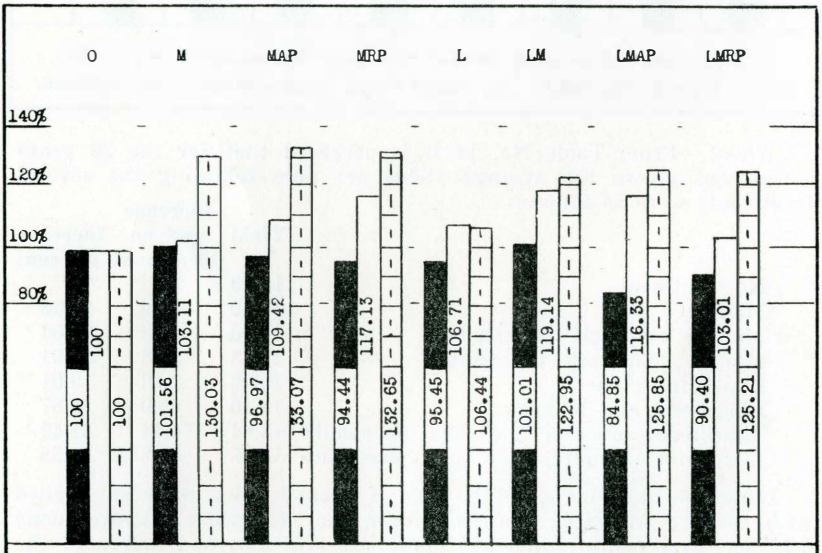

FIG. 15.-LEGUME YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

Legumes.—From Table No. 12 it may be observed that for the 19 years when it was possible for legume crops to produce seed the average yields of legume seed per acre for all crops following the several treatments were as follows:

	Yield lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	198		
Manure only	201	3	3.11
Manure and acid phosphate	192	–6	–3.03
Manure and rock phosphate	187	–11	–5.56
Limestone only	189	–9	–4.55
Limestone and manure	200	2	1.01
Limestone, manure and acid phosphate	168	–30	–15.15
Limestone, manure and rock phosphate	179	–19	–960

The minus sign (–) indicates decrease.

Manure alone increased the average yield three pounds of seed per acre over the yield following no treatment. All other treatments except manure and limestone decreased the yields and the yield following this treatment was one pound less than that following manure alone. The decreases were greater where limestone was applied.

The yields of legume straw following the several treatments are also recorded in Table No. 12 and the comparative yields of seed, straw and hay in per cent are shown graphically in Figure 15.

From Table No. 13 it may be observed that the average yields of legume hay following the several soil treatments for all legume crops were as follows:

	Yield lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	1,412		
Manure only	1,836	424	30.03
Manure and acid phosphate	1,879	467	33.07
Manure and rock phosphate	1,873	461	32.65
Limestone only	1,503	91	6.44
Limestone and manure	1,736	324	22.95
Limestone, manure, and acid phosphate	1,777	365	25.85
Limestone, manure and rock phosphate	1,768	356	25.21

Manure alone increased the average yield 424 pounds per acre over the yield following no treatment. Acid phosphate when applied with manure increased the yield 43 pounds over that following manure alone, and rock phosphate with manure increased the yield over manure alone 37 pounds.

There was an increase of 91 pounds per acre for the use of limestone over yields after no treatment, but where limestone was applied with manure or manure and phosphate the yields following the limestone addition were less than where limestone was omitted.

Summary.—Table No. 14 records the average yields for each crop, for all the years it was seeded, following the several soil treatments as well as the gain or loss in yield as compared with the yield following no treatment.

Table No. 15 records the total weights of all crops, including grain, seed, stalks, and hay, produced under all treatments during the 25 year period, 1913 to 1937, and the total weights of increases or

decreases in yield for the entire period following each treatment as compared with the plots receiving no treatment. From this table the average weights of total dry matter per acre per year have been computed and are recorded in the following Table No. 15a:

TABLE 15a.—Average Weight of Dry Matter of All Crops—Corn, Oats, Wheat and Legume—Per Acre Per Year Following Certain Soil Treatments at Brookings, S. D., 1913-1937

Treatment	Grain and Seed			Straw, Stalks, & Hay			Total Dry Matter		
	Lbs.	Lbs.	Per Cent	Lbs.	Lbs.	Per Cent	Lbs.	Lbs.	Per Cent
No Treatment	1,282.6			1,789.4			3,072.0		
Manure only	1,426.7	144.1	11.23	2,171.4	382.0	21.35	3,598.1	526.1	17.13
Manure and acid phosphate	1,458.0	175.4	13.68	2,207.2	417.8	23.35	3,665.2	593.2	19.31
Manure and rock phosphate	1,274.9	–7.7	–0.60	2,226.3	436.9	24.42	3,501.2	429.2	13.97
Limestone only	1,337.4	54.8	4.27	1,806.6	17.2	0.96	3,144.0	72.0	2.34
Limestone and manure	1,264.5	–18.1	–1.41	2,139.5	350.1	19.57	3,414.7	332.0	10.81
Limestone, manure, and acid phosphate	1434.0	151.4	11.80	2,164.3	374.9	20.95	3,598.3	526.3	17.13
Limestone, manure, and rock phosphate	1424.6	142.0	11.07	2,095.4	306.0	17.10	3,520.0	448.0	14.58

NOTE.—The averages are computed on the basis of 94 acre yields for grain and seed, and 93 acre yields for straw, stalks, and hay as no corn stalks were weighed in 1922. The average weight of legume seed is adjusted to a 22 years basis because the land was plowed to control quack grass immediately after cutting the hay in 1925, 1926, and 1927. The 22 year average is assumed to be the same as the actual 19 year average. See Tables No. 14 and No. 15.

Figure 16 shows graphically the percentage increases in comparative total weight of seed, grain, straw, stalks, and hay for the several soil treatments for the 25-year period.

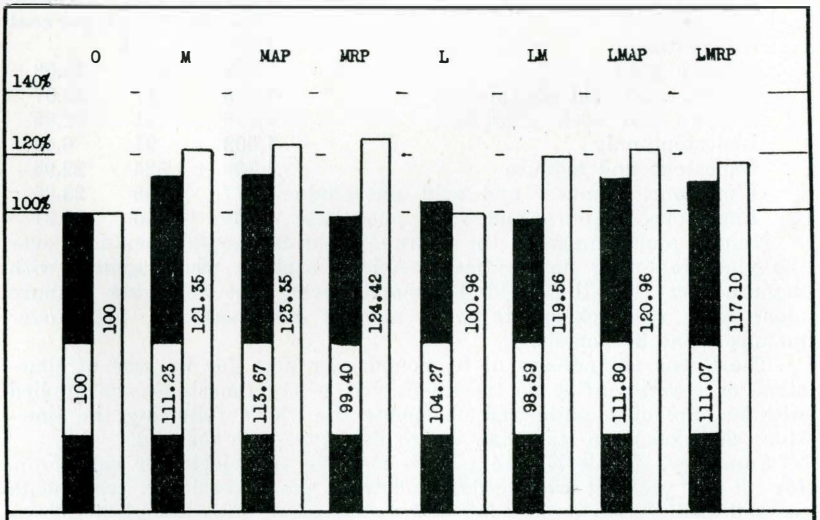

FIG. 16.—COMPARATIVE TOTAL WEIGHTS OF SEEDS, AND STRAW, STALKS, AND HAY OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW, STALKS, AND HAY YIELDS UNSHADED.

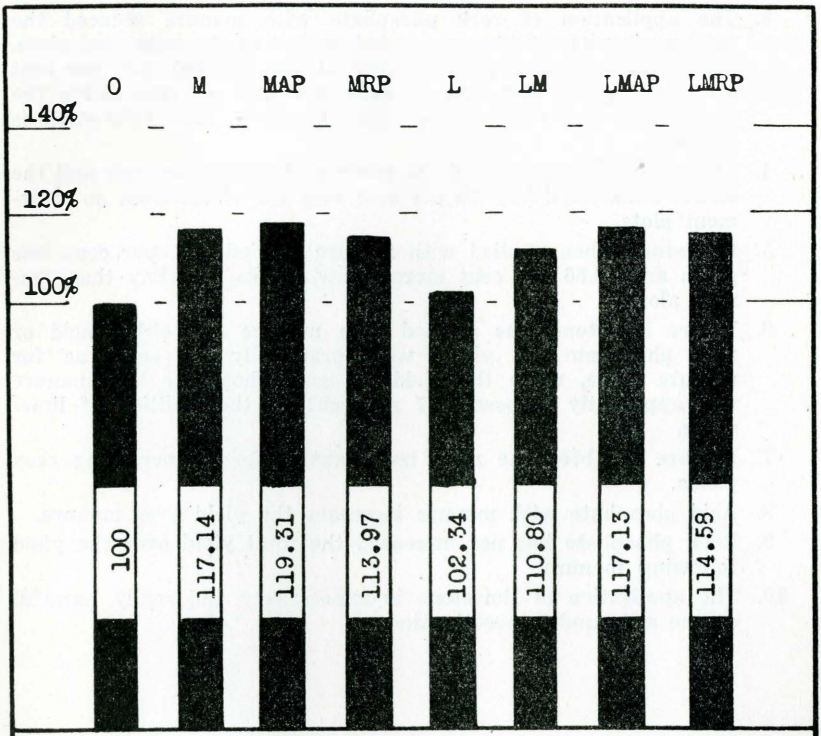

FIG. 17.-TOTAL WEIGHTS OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. CORN, OATS, WHEAT, LEGUME, FOR 25 YEARS.

Figure 17 shows graphically the percentage increases in the total weight of crops for the several soil treatments for 25 years.

Precipitation.—Attention is invited to the data and discussion concerning precipitation on pages 15 to 19 in Section I of this bulletin.

Conclusions.—From the results obtained over a period of 25 years, 1913 to 1937, the following conclusions may be drawn:

1. The application of 10 tons of manure once in the four-year rotation, preceding corn, has resulted in an increase of 11.25 per cent in total grain and seed crops over that from the plots receiving no treatment. The total yield of straw, stalks, and hay following the application of manure exceed the total yield of the same materials from plots receiving no treatment by 21.55 per cent.
2. The application of acid phosphate with manure increased the yield of grains 2.43 per cent and straw, stalks, and hay, 2.00 per cent.

3. The application of rock phosphate with manure reduced the total grain yields 0.60 per cent below that of the untreated plots, but it increased the yield of straw, stalks, and hay 3.07 per cent above the yields following manure and 1.07 per cent above the yields following manure and acid phosphate. No explanation is offered.
4. Limestone alone increased the grain yields 4.27 per cent and the straw, stalks, and hay .96 per cent over the yields from no treatment plots.
5. Limestone when applied with manure yielded 0.41 per cent less grain and 19.56 per cent more straw, stalks, and hay than manure alone.
6. Where limestone was applied with manure and either acid or rock phosphate the yields were practically the same as for manure alone, while the yield for acid phosphate and manure was apparently reduced 1.47 per cent by the addition of limestone.
7. Manure has been the most important factor in increasing crop yields.
8. Acid phosphate with manure increases the yield over manure.
9. Rock phosphate has not increased the total yield over the yield following manure.
10. The application of limestone is unnecessary and really harmful on the soils under investigation.

CORN

TABLE 9.—Yields of Corn, Following Phosphorus, Manure, and Limestone Treatments at Brookings, S. Dak., Rotation No. 1

Treatment		None		Manure		M.AP		M.RP		None		Limestone		M.L.		M.L.AP		M.L.RP		None		Average None	
Plot No.		–40		–41		–42		–43		–44		–45		–46		–47		–48		–49			
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1913	540-9	47.00	1650	45.38	1400	43.25	1200	44.23	1550	46.56	1200	39.60	1100	43.98	1300	44.61	1450	41.97	1050	46.71	1400	46.76	1417
1914	440-9	49.64	1550	54.57	1720	53.07	1750	54.67	1850	51.11	1650	51.67	1700	56.53	1700	52.94	1700	53.45	1650	48.41	1500	49.72	1567
1915	340-9	20.71	1900	29.38	2500	32.06	3000	30.07	2600	23.77	2050	25.50	2050	30.67	2450	30.76	2600	28.34	2200	20.41	1900	21.63	1950
1916	240-9	43.55	2250	44.24	2400	47.90	2450	47.50	2500	46.00	2400	45.33	2220	48.44	2450	44.51	2670	51.35	2800	45.05	2450	44.87	2367
1917	540-9	37.41	2350	36.48	2900	36.60	2800	37.80	2950	33.24	1750	33.24	1850	36.24	2500	33.11	2500	38.16	2400	33.73	1850	34.79	1983
1918	440-9	50.84	1650	59.08	2050	60.00	2150	62.07	2350	52.20	1050	51.77	1750	57.85	1850	57.67	2100	56.03	2200	50.57	1450	51.20	1383
1919	340-9	35.88	2000	61.00	3850	69.50	3750	65.50	3350	56.88	2250	53.88	2200	55.13	2500	63.10	2650	63.13	2600	38.13	1250	43.63	1833
1920	240-9	49.43	2000	65.57	3050	62.28	1900	70.85	3750	68.57	2700	66.85	3250	74.71	3350	71.85	3500	72.85	3050	66.85	2900	61.62	2533
1921	540-9	53.85	1500	62.43	2250	66.43	1950	64.85	2050	52.85	1100	45.57	1200	46.14	1450	42.71	1250	47.28	1500	45.85	1150	50.85	1250
1922	440-9	19.57	--	16.86	--	23.00	--	20.28	--	25.71	--	21.00	--	25.14	--	24.28	--	21.14	--	23.00	--	22.76	--
1923	340-9	51.43	2000	64.85	3050	63.71	3350	63.00	3050	59.14	2500	57.85	2100	62.43	3000	62.14	2950	61.14	3000	53.71	3490	54.76	2663
1924	240-9	31.43	1000	42.86	1500	50.28	2100	52.71	2150	46.28	1750	46.71	1400	56.43	2250	58.14	1900	55.57	2100	40.00	1450	39.24	1400
1925	540-9	23.14	1000	24.43	1150	26.00	1350	25.43	1150	24.14	900	23.86	1100	24.28	1150	24.43	1200	26.14	1150	33.71	1200	27.00	1033
1926	440-9	49.14	1250	51.55	1350	53.29	1150	50.75	1500	43.38	1150	47.97	1200	49.81	1400	40.30	1350	40.21	1150	39.07	1100	43.86	1167
1927	340-9	50.00	2650	58.00	3000	57.35	2950	58.71	3050	54.85	2600	58.14	2400	57.14	3000	54.43	3050	52.64	2800	48.57	2600	51.14	2617
1928	240-9	34.00	750	34.86	1100	37.00	1200	36.14	1250	19.28	1350	39.28	950	40.71	1250	41.86	1800	37.86	1900	35.00	1550	29.43	1217
1929	540-9	54.76	2550	55.55	1575	53.96	1650	53.17	1300	53.96	1300	47.62	1375	53.57	1100	48.41	1400	51.98	1450	48.41	1325	52.38	1725
1930	440-9	18.14	2070	14.43	2710	12.00	2620	13.14	2660	20.14	1970	18.28	2160	12.29	2840	9.43	2760	9.00	2750	15.71	2280	18.00	2107
1931	340-9	11.14	1690	7.57	1880	7.57	1920	8.14	2040	9.57	2000	9.71	1940	8.43	2140	7.14	2330	7.00	2420	15.43	2230	12.05	1973
1932	240-9	29.43	1510	28.14	1830	27.71	2030	29.28	1900	32.86	1550	33.86	1500	29.43	1890	28.00	1790	30.71	1900	34.57	1330	32.29	1463
1933	540-9	5.99	933	5.63	1175	4.68	975	3.73	1115	8.02	955	9.52	870	3.17	700	2.42	858	3.17	850	6.51	730	6.84	873
1934	440-9	13.71	1220	14.29	1200	14.29	1300	13.71	1220	14.57	1110	15.43	1070	15.28	1210	13.14	1080	12.29	1020	11.43	1420	13.24	1250
1935	340-9	26.80	1876	43.71	1910	43.67	1663	47.15	1719	42.23	2044	41.46	1848	47.87	1949	44.45	2088	47.77	2156	38.04	1837	35.69	1919
1936	240-9	Complete failure due to drought.																					
1937	540-9	39.46	1563	41.78	1688	34.28	1500	26.87	1375	25.00	813	21.78	875	21.25	813	23.66	938	22.68	1125	27.86	1188	30.77	1188
25 Yrs. Average*		33.86	1621	38.51	1968	39.20	1946	39.19	2017	36.41	1589	36.24	1588	38.28	1843	36.94	1913	37.27	1884	34.67	1649	34.98	1620
Increase over "Av. of None"				3.53	348	4.22	326	4.21	397			1.26	–32	3.30	223	1.96	293	2.29	264				
Increase per cent				10.09	21.48	12.06	20.12	12.04	24.51			3.60	–1.98	9.43	13.77	5.60	18.09	6.55	16.30				

NOTE.—The minus (–) sign indicates decrease. * The average for stalks is for 24 years only. Stalks record lacking for 1922.
None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

OATS

TABLE 10.—Yields of Oats, Following Phosphorus, Manure, and Limestone Treatments at Brookings, S. Dak., Rotation No. 1

Treatment / Plot No.		None -40		Manure -41		M.AP -42		M.RP -43		None -44		Limestone -45		M.L. -46		M.L.AP -47		M.L.RP -48		None -49		Average None	
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1914	540-9	33.59	2785	28.28	3195	28.90	3055	26.40	2845	35.63	3000	34.06	2870	25.47	2855	23.59	2670	35.63	2860	38.13	2135	35.78	2640
1915	440-9	92.50	2800	94.06	3180	92.50	3140	93.75	3170	88.75	2910	90.63	3020	95.63	3320	94.06	2940	102.81	3120	92.19	2770	91.15	2827
1916	340-9	58.44	1630	72.19	2340	76.25	2510	75.63	2350	64.06	1680	65.63	1730	76.56	2200	77.50	2170	76.88	2290	72.50	1750	65.00	1687
1917	240-9	92.50	2340	104.69	2550	106.88	2440	113.75	2660	100.94	2340	103.13	2450	106.25	2310	110.31	2470	106.56	2370	98.13	2220	97.19	2300
1918	540-9	41.88	1660	46.88	1950	50.94	2040	47.50	1680	44.06	1320	42.50	1240	45.63	1450	45.94	1480	42.50	1420	38.13	1110	41.36	1363
1919	440-9	55.00	1650	62.50	1980	65.00	2020	59.06	2030	55.31	1730	58.13	1640	58.13	1990	56.25	1850	56.88	1880	52.25	1600	54.19	1660
1920	340-9	31.25	2270	34.69	1500	36.56	1580	52.19	1680	46.56	1440	44.69	1650	46.56	1860	55.31	1780	54.38	1660	46.88	1670	41.56	1793
1921	240-9	36.25	1050	42.81	1460	43.13	1760	48.13	1590	38.75	1130	37.50	1060	41.25	1520	45.94	1680	45.63	1670	36.25	1080	37.08	1087
1922	540-9	45.63	1490	51.88	1850	54.38	1800	57.50	1760	44.69	1240	46.25	1070	54.06	1640	54.38	1600	55.31	1430	44.06	1010	44.79	1247
1923	440-9	46.25	1740	55.31	2640	60.94	2150	60.63	2130	65.63	1980	64.06	1940	60.63	2060	60.94	2200	57.50	2110	61.56	2070	57.81	1930
1924	340-9	67.81	2330	75.94	2970	76.88	2540	80.63	3020	74.69	1650	73.75	2280	81.25	2500	78.75	2780	77.50	2420	80.31	3030	74.27	2337
1925	240-9	58.44	1830	65.31	3110	36.25	3500	60.00	3280	56.25	2300	60.31	2070	64.06	2750	67.81	3030	64.06	2950	59.38	2400	58.02	2177
1926	540-9	18.75	1420	23.44	2710	32.50	1900	20.31	1550	17.50	1540	23.75	1240	30.31	1770	32.50	1680	30.63	1600	--*	--	18.13	1480
1927	440-9	34.06	1140	47.19	1530	49.38	1470	51.56	1480	38.75	1060	55.31	1660	38.44	1080	49.06	1360	53.13	1470	37.19	990	36.67	1063
1928	340-9	26.25	2040	45.00	1740	55.63	1640	57.81	1630	40.31	2010	49.38	1520	62.50	2060	64.06	2290	62.50	2360	46.56	1950	37.71	2000
1929	240-9	35.63	1160	57.19	2020	62.50	1850	58.13	2390	41.25	1130	45.31	850	60.00	1430	64.38	1490	62.50	1500	43.13	1170	40.00	1153
1930	540-9	47.22	1100	59.72	1440	60.76	1450	60.07	1370	47.22	970	48.96	990	59.03	1310	58.68	1310	60.76	1340	46.18	920	46.87	997
1931	440-9	20.00	1060	24.06	1280	25.00	1450	24.38	1620	20.31	1150	18.13	1540	24.69	1560	23.75	1740	20.31	1750	20.63	1420	20.31	1210
1932	340-9	57.50	2280	60.63	2200	58.75	2340	60.31	2410	65.63	2040	55.31	2250	69.38	2320	68.75	2440	70.31	2090	72.81	2370	65.31	2230
1933	240-9	3.13	800	3.44	390	2.50	620	2.81	610	2.81	610	4.06	570	4.06	520	3.13	500	3.75	580	3.75	630	3.23	680
1934	540-9	Failure due to drought.																					
1935	440-9	57.50	1840	61.88	1980	60.94	1950	59.38	1900	64.38	2060	63.13	2020	61.88	1980	61.25	1960	56.88	1820	68.75	2200	63.54	2033
1936	340-9	33.75	1320	30.00	1640	32.19	1770	32.81	1750	32.81	1450	33.44	1430	37.50	1600	36.25	1940	41.25	1780	39.38	1940	35.31	1570
1937	240-9	49.38	2120	49.69	1210	44.06	1540	45.94	1280	45.31	1550	42.50	1240	46.56	1510	44.69	1320	40.63	1300	41.25	580	45.31	1417
24 Yrs. Average		43.45	1661	49.87	1953	50.53	1938	52.03	1924	47.15	1595	48.33	1597	52.08	1816	53.22	1862	53.26	1824	48.23	1604	46.27	1620
Increase over "Av. of None"				3.60	333	4.26	318	5.76	304			2.06	-23	5.81	196	6.95	242	6.99	204				
Increase per cent				7.78	20.56	9.21	19.63	12.45	18.77			4.45	-1.42	12.56	12.10	15.02	14.94	15.11	12.59				

NOTE.—The minus (-) sign indicates decrease. None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

* Record missing for Plot 549 for 1926. Average yields of grain and straw on Plots 540 and 544 used in computing 24 year average.

WHEAT

TABLE 11.—Yields of Wheat, Following Phosphorus, Manure, and Limestone Treatments at Brookings, S. Dak., Rotation No. 1

Treatment		None		Manure		M.AP		M.RP		None		Limestone		M.L.		M.L.AP		M.L.RP		None		Average None	
Plot No.		−40		−41		−42		−43		−44		−45		−46		−47		−48		−49			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1915	540-9	43.33	2870	46.16	3630	47.00	3370	47.00	3330	33.33	2500	39.00	2800	41.33	2970	43.33	3000	34.33	2490	36.33	2610	37.67	2660
1916	440-9	17.67	1940	19.83	2020	21.17	2130	17.83	1790	14.67	1520	15.67	1690	22.50	2350	22.83	2400	20.67	2250	13.50	1540	15.28	1667
1917	340-9	23.17	2490	26.50	3160	29.17	3500	23.33	2980	21.17	2850	21.00	2860	22.50	3400	23.00	3350	22.67	3340	20.33	2680	20.56	2673
1918	240-9	21.83	1550	20.67	1480	19.33	1440	19.83	1510	20.50	1400	20.83	1450	17.50	1320	16.50	1260	16.17	1330	17.00	1230	19.78	1393
1919	540-9	10.67	1410	16.17	2380	15.17	2240	12.00	1960	7.17	1320	6.17	1130	9.00	1590	7.67	660	7.00	1290	2.00	530	6.61	1087
1920	440-9	3.33	920	9.67	1890	13.67	2600	10.17	2170	4.00	960	5.00	1330	9.00	2460	11.00	2860	8.00	2040	3.33	870	3.55	917
1921	340-9	4.33	1210	10.00	1850	10.50	1820	8.00	1490	5.83	1050	7.00	1280	10.83	2030	12.50	2110	12.33	2220	9.83	1660	6.66	1307
1922	240-9	13.33	1530	18.17	1720	18.67	1590	27.17	2230	17.17	1390	18.50	1580	23.00	1790	24.00	1670	23.33	1880	17.33	1610	15.94	1510
1923	540-9	8.00	2020	9.83	2210	8.33	2900	9.00	2460	9.67	2220	9.67	1620	10.00	2100	9.00	1760	8.83	1770	10.00	1750	9.22	1997
1924	440-9	36.33	2860	47.83	3860	54.83	3940	51.83	4100	38.67	3180	40.17	3330	51.33	3850	57.66	4310	50.00	4040	33.33	3300	36.11	3080
1925	340-9	6.83	1190	8.33	2300	13.67	2380	6.17	2030	4.00	2060	6.33	1820	14.17	2250	20.50	2270	17.00	2280	10.50	2270	7.11	1840
1926	240-9	1.00	1000	.67	1240	1.17	1830	1.00	2000	1.00	1700	1.67	1600	1.17	2070	1.17	1790	1.08	1975	1.50	1310	1.17	1337
1927	540-9	18.89	1480	21.67	1610	23.33	1950	19.44	2900	14.07	1360	16.67	1170	20.37	1810	15.37	2320	21.11	2110	15.37	1040	16.11	1293
1928	440-9	No crop—winter-killed.																					
1929	340-9	21.25	2325	27.25	2865	28.17	2810	29.50	2930	27.83	2630	29.50	2680	35.17	3340	34.50	3380	32.67	3040	29.50	2830	26.19	2595
1930	240-9	25.33	1830	33.17	2300	33.33	2420	34.00	2420	23.33	1600	28.00	1910	34.67	2420	35.17	2490	33.83	2590	26.00	1800	24.89	1743
1931	540-9	11.11	1090	7.41	1150	6.30	1360	5.37	1270	5.93	1090	7.41	1140	4.07	1230	3.70	1120	4.07	1180	7.59	1090	8.21	1090
1932	440-9	23.67	1780	27.67	2640	26.83	1990	24.17	2250	22.00	1960	26.17	2090	31.33	2240	29.50	2310	28.50	2250	23.33	1900	23.00	1880
1933	340-9	6.00	800	6.00	980	6.33	920	6.33	870	6.17	1080	7.67	990	10.00	1050	10.00	1200	8.83	1170	9.83	1410	7.33	1097
1934	240-9	Complete failure due to drought.																					
1935	540-9	31.67	2260	38.54	2550	40.62	2850	41.25	2620	32.29	2390	37.92	2520	40.42	2760	41.04	2790	40.42	2800	32.29	2470	32.08	2373
1936	440-9	Completely winter-killed.																					
1937	340-9	6.67	2250	4.50	2890	6.00	2640	5.17	2240	4.00	1810	6.00	2090	8.00	3770	7.75	2985	7.00	2330	9.75	2925	6.81	2328
23 Yrs. Average		14.54	1513	17.39	1948	18.42	2030	17.33	1980	13.60	1568	15.23	1525	18.10	2035	18.54	2002	17.28	1929	14.29	1601	14.10	1559
Increase over "Av. of None"				3.29	389	4.32	471	3.23	421			1.13	−34	4.00	476	4.44	443	3.18	370				
Increase per cent				23.33	24.95	30.64	30.21	22.91	27.00			8.01	−2.18	28.37	30.53	31.49	28.42	22.55	23.73				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

TABLE 12.—Yields of Legume Seed and Straw, Following Phosphorus, Manure, and Limestone Treatments at Brookings, S. Dak., Rotation No. 1

Treatment Plot No.			None -40		Manure -41		M.AP. -42		M.RP. -43		None -44		Limestone -45		M.L. -46		M.L.AP. -47		M.L.RP. -48		None -49		Average of None	
Year	Yield Acre	Crop	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw	Lbs. Seed	Lbs. Straw
1916	540-9	R.Cl.	85	910	50	1150	70	1350	80	1330	107	1260	92	1310	100	1420	80	1000	107	1060	107	890	100	1026
1917	440-9	R.Cl.	Second crop cut for hay. No seed.																					
1918	340-9	R.Cl.	Second crop cut for hay. No seed.																					
1919	240-9	R.Cl.	Second crop cut for hay. No seed.																					
1920	540-9	S.Cl.	250	3150	260	3890	185	4015	180	4450	175	2475	130	2820	140	4560	140	4760	210	4190	240	3360	222	2995
1921	440-9	S.Cl.	300	840	420	940	430	1670	510	1790	390	1210	500	1700	400	1200	320	1480	380	1420	410	1490	367	1180
1922	340-9	S.Cl.	380	970	410	1490	420	1180	420	1880	490	1910	440	2460	520	2530	430	2520	420	1680	590	3410	487	2097
1923	240-9	S.Cl.	520	3180	440	3760	370	4330	340	3960	440	3660	520	3880	380	4220	250	3950	320	3080	530	3970	497	3603
1924	540-9	S.Cl.	285	1815	370	2330	470	2830	410	2790	410	2290	375	2525	415	2585	370	2830	315	2685	310	2590	335	2232
1925	440-9	S.Cl.	Plowed immediately after first cutting to kill quack grass. No seed crop.																					
1926	340-9	S.Cl.	Plowed immediately after first cutting to kill quack grass. No seed crop.																					
1927	240-9	S.Cl.	Plowed immediately after first cutting to kill quack grass. No seed crop.																					
1928	540-9	S.Cl.	150	1550	125	2175	150	1710	80	2140	120	1520	100	1740	110	1890	110	2230	110	1770	200	2220	157	1763
1929	440-9	S.Cl.	280	1620	330	1290	255	1225	290	1350	375	1525	410	1390	355	1585	270	890	245	1295	360	1300	338	1482
1930	340-9	S.Cl.	40	560	35	565	35	715	25	675	35	665	30	770	40	760	25	675	20	680	35	765	37	663
1931	240-9	S.Bn.	320	730	300	600	200	650	260	740	300	880	340	660	300	800	270	630	330	570	420	660	347	757
1932	540-9	S.Bn.	840	1160	840	1060	820	780	730	820	500	750	420	680	800	750	700	800	700	800	560	690	633	867
1933	440-9	R.Cl.	No Yield on account of drought.																					
1934	340-9	R.Cl.	No yield on account of drought.																					
1935	240-9	R.Cl.	Complete failure. Seeded to soy beans which were cut for hay.																					
1936	540-9	R.Cl.	Failed. Seeded to soy beans.																					
1936	540-9	S.Bn.	235	295	235	295	235	295	235	295	235	295	235	295	235	295	235	295	235	295	235	295	235	295
1937	440-9	R.Cl.	Complete failure.																					
Average R.Cl. 9 Yrs.			9	101	6	128	8	150	9	148	12	140	10	146	11	158	9	111	12	118	12	99	11	113
Average S.Cl. 8 Yrs.			276	1711	299	2055	289	2209	282	2379	304	1907	313	2161	295	2416	239	2417	253	2100	334	2388	305	2002
Average S.Bn. 4 Yrs.			349	546	344	489	314	431	306	464	259	481	249	409	334	461	301	431	316	416	304	411	304	480
Av. All Crops 19 Yrs.			194	883	201	1029	192	1092	187	1169	188	971	189	1065	200	1189	168	1161	179	1028	210	1139	198	998
Increase all crops over "Av. of None"					3	31	−6	94	−11	171			−9	67	2	191	−30	163	−19	30				
Increase per cent					1.56	3.11	−3.03	9.42	−5.56	17.13			−4.55	6.71	1.01	19.14	−15.15	16.33	−9.60	3.01				

NOTE.—The minus (−) sign indicates decrease. R.Cl.—Red Clover S.Cl.—White Sweet Clover S.Bn.—Soy Beans
None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

TABLE 13.—Yields of Legume Hay, Following Phosphorus, Manure, and Limestone Treatments at Brookings, S. Dak., Rotation No. 1

Year	Acre	Crop	Cut	None −40 Cut	None −40 Total	Manure −41 Cut	Manure −41 Total	M.AP −42 Cut	M.AP −42 Total	M.RP −43 Cut	M.RP −43 Total	None −44 Cut	None −44 Total	Limestone −45 Cut	Limestone −45 Total	M.L. −46 Cut	M.L. −46 Total	M.L.AP −47 Cut	M.L.AP −47 Total	M.L.RP −48 Cut	M.L.RP −48 Total	None −49 Cut	None −49 Total	Average of None Cut	Average of None Total
1916	540-9	R.Cl.	1		2500		3900		3900		4000		2250		2350		3300		3600		2500		1750	2167	2167
1917	440-9	R.Cl.	1	830		1150		1100		820		690		880		1160		1840		1720		890		803	
1917	440-9	R.Cl.	2	1600	2430	1650	2800	1900	3000	2200	3020	1400	2090	1600	2480	2050	3210	1700	3540	2100	3820	2250	3140	1750	2553
1918	340-9	R.Cl.	1	750		1200		1400		1100		950		800		1750		1500		1550		1100		933	
1918	340-9	R.Cl.	2	950	1700	1120	2320	870	2270	820	1970	800	1750	830	1630	880	2630	980	2480	1150	2700	1040	2140	930	1863
1919	240-9	R.Cl.	1	630		950		990		1040		500		540		730		990		680		500		543	
1919	240-9	R.Cl.	2	4100		4900		5000		4750		3900		4000		4300		4600		4350		4000		4000	
1919	240-9	R.Cl.	3	2700	7430	3050	8900	3150	9140	3350	9140	2650	7050	3100	7640	2800	7830	3000	8590	2950	7980	2700	7200	2683	7227
1920	540-9	S.Cl.	1	2130	2130	1920	1920	2250	2250	2100	2100	1530	1530	1680	1680	1650	1650	1590	1590	1890	1890	1530	1530	1730	1730
1921	440-9	S.Cl.	1	1400	1400	2950	2950	3550	3550	2800	2800	1150	1150	1550	1550	2350	2350	2400	2400	2750	2750	1800	1800	1450	1450
1922	340-9	S.Cl.	1	No hay—cut for seed.																					
1923	240-9	S.Cl.	1	No hay—cut for seed.																					
1924	540-9	S.Cl.	1	680	680	850	850	1260	1260	1040	1040	490	490	470	470	650	650	1000	1000	770	770	550	550	573	573
1925	440-9	S.Cl.	1	3200	3200	3250	3250	3100	3100	3750	3750	3600	3600	3050	3050	3000	3000	3300	3300	3000	3000	3050	3050	3283	3283
1926	340-9	S.Cl.	1	550	550	1050	1050	450	450	1200	1200	870	870	930	930	1300	1300	950	950	1450	1450	1200	1200	873	873
1927	240-9	S.Cl.	1	1430	1430	1730	1730	1360	1360	1850	1850	1440	1440	1420	1420	1770	1770	1810	1810	1780	1780	1450	1450	1440	1440
1928	540-9	S.Cl.	1	2280	2280	2220	2220	2500	2500	2060	2060	1890	1890	1940	1940	2110	2110	2060	2060	2500	2500	2560	2560	2243	2243
1929	440-9	S.Cl.	1	2300	2300	2900	2900	3000	3000	3175	3175	2775	2775	3750	3750	3100	3100	2475	2475	2300	2300	2200	2200	2425	2425
1930	340-9	S.Cl.	1	2280	2280	2300	2300	2450	2450	1700	1700	1550	1550	1750	1750	1800	1800	2500	2500	2000	2000	2220	2220	2017	2017
1931	240-9	S.Cl.	1	Sweet clover failed. Soy beans substituted.																					
1932	540-9	S.Cl.	1	Sweet clover failed. Soy beans substituted.																					
1933	440-9	S.Cl.	1	No yield due to drought.																					
1934	340-9	R.Cl.	1	Complete failure due to drought. Seeded to Bison flax which also failed.																					
1935	240-9	R.Cl.	1	Killed by drought in 1934. Soy beans substituted.																					
1935	240-9	S.BHay		1800	1800	3300	3300	3100	3100	3400	3400	2150	2150	2430	2430	3500	3500	2800	2800	3450	3450	2700	2700	2217	2217
1936	540-9	S.Cl.	1	Sweet clover failed due to drought. Soy beans substituted.																					
1937	440-9	R.Cl.	1	Complete failure.																					
AV. ALL CROPS 22 YRS.					1460		1836		1879		1873		1390		1503		1736		1777		1768		1522		1412
Increase over "Av. of None"							424		467		461				91		324		365		356				
Increase per cent							30.03		33.07		32.65				6.44		22.95		25.85		25.21				

None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

SUMMARY

TABLE 14.—Summary of the Results From All Treatments on All Crops—Corn, Oats, Wheat, Legumes—in Rotation No. 1 at Brookings, S. D., Expressed as Weighted Averages

Crop	Corn-Grain		Corn-Stalks		Oats-Grain		Oats-Straw		Wheat-Grain		Wheat-Straw		Legume-Seed		Legume-Straw		Legume-Hay	
No. of Yrs.	25		24		24		24		23		23		22		22		22	
Treatment	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.
None	34.98		1620		46.27		1620		14.10		1559		198		988		1412	
Manure	38.51	3.53	1968	348	49.87	3.60	1953	**333**	17.39	3.29	1948	389	201	**3**	1029	51	1836	424
M.AP.	39.20	**4.22**	1946	326	50.53	4.26	1938	318	18.42	4.32	2030	471	192	−6	1092	94	1879	**467**
M.RP.	39.19	4.21	2017	**397**	52.03	5.76	1924	304	17.33	3.23	1980	421	187	−11	1169	171	1873	461
Limestone	36.24	1.26	1588	−32	48.33	2.06	1597	−23	15.23	1.13	1525	−34	189	−9	1065	67	1503	91
M.L.	38.28	3.30	1843	223	52.08	5.81	1816	196	18.10	4.00	2035	**476**	200	2	1189	**191**	1736	324
M.L.AP.	36.94	1.96	1913	293	53.22	6.95	1862	242	18.54	**4.44**	2002	443	168	−30	1161	163	1777	365
M.L.RP.	37.27	2.29	1884	264	53.26	**6.99**	1824	204	17.28	3.18	1929	370	179	−19	1028	30	1768	356

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Manure	10.09	21.48	7.78	**20.56**	23.33	24.95	**1.56**	3.11	30.03
M.AP.	**12.06**	20.12	9.21	19.63	30.64	30.21	−3.03	9.42	**33.07**
M.RP.	12.04	**24.51**	12.45	18.77	22.91	27.00	−5.56	17.13	32.65
Limestone	3.60	−1.98	4.45	−1.42	8.01	−2.18	−4.55	6.71	6.44
M.L.	9.43	13.77	12.56	12.10	28.37	**30.53**	1.01	**19.14**	22.95
M.L.AP.	5.60	18.09	15.02	14.94	**31.49**	28.42	−15.15	16.33	25.85
M.L.RP.	6.55	16.30	**15.11**	12.59	22.55	23.73	−9.60	3.01	25.21

NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment.
The figures indicating the greatest increase in yield in each crop are printed in bold face type.
None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

GENERAL SUMMARY

TABLE 15.—General Summary of the Results From All Treatments on All Crops: Corn, Oats, Wheat, Legumes, in Rotation No. 1 Expressed in Terms of the Total Amounts of Dry Matter Produced Per Acre, at Brookings, S. Dak.

Crop	No. Yrs.	None Grain Lbs.	Manure Grain Lbs.	M.AP. Grain Lbs.	M.RP. Grain Lbs.	Limestone Grain Lbs.	M.L. Grain Lbs.	M.L.AP. Grain Lbs.	M.L.RP. Grain Lbs.
Corn	25	61,215	67,393	68,600	68,583	63,420	49,490	64,645	65,223
Oats	24	35,535	38,300	38,807	23,232	37,117	39,997	40,873	40,904
Wheat	23	19,458	23,998	25,420	23,915	21,017	24,978	25,585	23,846
Legume Seed	22	4,356	4,422	4,224	4,114	4,158	4,400	3,696	3,938
Total	(94)	120,564	134,113	137,051	119,844	125,712	118,865	134,799	133,911
Total Gain		--	13,549	16,487	–720	5,148	–1,699	14,235	13,347
Av. Gain per Yr.		--	144.1	175.4	–7.7	54.8	–18.1	151.4	142.0
Gain per cent		--	11.23	13.67	–0.60	4.27	–1.41	11.80	11.07

		Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay
Corn	24	38,880	47,232	46,704	48,408	38,112	44,232	45,912	45,216
Oats	24	38,880	46,872	46,512	46,176	38,328	43,584	44,688	43,776
Wheat	23	35,857	44,804	46,690	45,540	35,075	46,805	46,046	44,367
Legume Straw	22	21,736	22,638	24,024	25,718	23,430	26,158	25,542	22,616
Legume Hay	22	31,064	40,392	41,338	41,206	33,066	38,192	39,094	38,896
Total	(93)	166,417	201,938	205,268	207,048	168,011	198,971	201,282	194,871
Total Gain		--	35,521	38,851	40,631	1,594	32,554	34,865	28,454
Av. Gain per Yr.		--	381.9	417.8	436.9	17.1	350.0	374.9	306.0
Gain per cent		--	21.35	23.35	24.42	0.96	19.56	20.96	17.10

Total Amount of Dry Matter Produced Under the Several Treatments

	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay
Corn	100,095	114,625	115,304	116,991	101,532	93,722	110,557	110,439
Oats	74,415	85,172	85,319	69,408	75,445	83,581	85,561	84,680
Wheat	55,315	68,802	72,110	69,455	56,092	71,783	71,631	68,206
Legumes	57,156	67,452	69,586	71,038	60,654	68,750	68,332	65,450
Total	286,981	336,051	342,319	326,892	293,723	317,836	336,081	328,782
Total Gain	--	49,070	55,338	39,911	6,742	30,855	49,100	41,801
Av. Gain per Yr.	--	526.0	593.2	429.2	71.9	331.9	526.3	448.0
Gain per cent	--	17.14	19.31	13.97	2.34	10.80	17.13	14.58

General Summary of the Increases in Yield for the Several Treatments Over No Treatment for All Crops Grown

Total Gain Grain	13,549	16,487	–720	5,148	–1,699	14,235	13,347
Total Gain Straw, etc.	35,521	38,851	40,631	1,594	32,554	34,865	28,454
Total Gain Dry Matter	49,070	55,338	39,911	6,742	30,855	49,100	41,801
Gain Per Cent Grain	11.23	13.67	–0.60	4.27	–1.41	11.80	11.07
Gain Per Cent Straw, etc.	21.35	23.35	24.42	0.96	19.56	20.96	17.10
Gain Per Cent Total Dry Matter	17.14	19.31	13.97	2.34	10.80	17.13	14.58

NOTE.—The minus (–) sign indicates decrease.
The average yields per acre per year for None (No Treatment) for all crops were: Grain, 1283 lbs.; straw, etc., 1789 lbs.; total, 3072 lbs.

None—no treatment. M—manure. AP—acid phosphate. RP—rock phosphate. L—limestone.

Section III. Grain and Livestock Farming Systems At Brookings, S. D.

Introduction.—The results here reported have been obtained from investigations under an experiment station project supported by allotments from the Hatch fund. This fund is from appropriations made by the Congress of the United States as authorized by the Hatch Act. The allotment of funds for the project is made by the director of the experiment station.

History.—This project was begun in 1913 and has been continued without interruption. The results for the 25 years ending in 1937 are summarized in this report.

Object.—In South Dakota many farms produce grain crops for sale while others produce grain and forage to be fed to livestock. It has often been said that the fertility of the soil can best be maintained by practicing a livestock farming system. It is also true that under the soil and climatic conditions in South Dakota marketable grain has been an important product.

Not all farmers are suited to the livestock business even were it possible for every one to engage in it from the standpoint of economic return. Livestock farmers must have an adequate supply of feed and many of them purchase feed raised on farms where livestock is not fed. If they are to purchase feed from such farms the soils of these grain farms must be so managed as to be permanently productive, else the supply of feed will fail as well as the grain farmer himself.

Organic matter is regarded as one of the essential substances in soils and as the supply in the soil decreases unless regularly replenished it appears that all soils under whatever system of farming a supply of this important substance must be maintained. This project was planned to make such a provision.

Since available phosphorus had already been shown to be wanting in the complete fertility project (see Section I of this report) provision was made for the application of phosphorus, and also potassium.

It was proposed to ascertain, as indicated by the crop yields:

1. The relative effectiveness of grain and livestock systems of farming in maintaining soil productivity.
2. The effects of applying certain amounts of phosphorus and potassium in maintaining soil fertility when applied with organic matter.
   a. In the form of barnyard manure;
   b. In the form of crop residues and legumes plowed under.

Plan of the Work.—This project is located on three acres of land situated on the "West Farm" at Brookings, S. D.

Figure 18 shows the plan of the plots, their numbers, and treatment applied. Each plot is two rods wide and eight rods long. The area is 16 square rods or one tenth of an acre. The plots in each acre are separated by alleys 40 inches in width and which for most of the years have been

R	360
RL	361
RLP	362
RLK	363
RLPK	364
O	365
M	366
MP	367
MK	368
MPK	369

R	460
RL	461
RLP	462
RLK	463
RLPK	464
O	465
M	466
MP	467
MK	468
MPK	469

R	560
RL	561
RLP	562
RLK	563
RLPK	564
O	565
M	566
MP	567
MK	568
MPK	569

ROTATION NO. 22.

CORN-OATS-LEGUME: GRAIN & LIVESTOCK FARMING SYSTEM.

EXPERIMENT STATION, BROOKINGS, S.DAK.

Fig. 18.—Plan of the Grain and Livestock Farming Systems Plots at Brookings, S. D.
The letters indicate the kind of soil treatment applied:
O means nothing applied.
R means crop residues including straw, stalks, and first cuttings of legume crop plowed under.
L Means peas plowed under.
M means manure plowed under.
P means phosphorus applied in the form of acid phosphate at the rate of 200 pounds per acre.
K means potassium applied in the form of potassium chloride at the rate of 200 pounds per acre.
These letters have the same meaning wherever they occur in this project.

kept free of weeds by frequent cultivation. More recently the whole acre, plots and alleys, has been planted and at harvest time the crop in the alleys has been removed before harvesting the crops from the plots.

Soil.—The soil on these plots is Barnes sandy loam and has the same general characteristics as the soil described under Sections I and II of this report. See page 9 or page 25.

Soil Preparation.—In this rotation, No. 22, at the Brookings experiment farm, the land is fall plowed seven inches deep for the following corn crop. Following the corn crop the corn stubble on the livestock system and the corn stalks on the grain farming system are disked in pre-

paring for the seeding of oats. The legume crop, red clover or sweet clover, is broadcast as a catch crop at the time of seeding the oats. Where it has been necessary to substitute soy beans because of the failure of clover the land has been plowed in the spring.

Applicatiton of Organic Matter.—In the grain farming system the organic matter is applied in the form of crop residues and legumes. All oat straw, the first cutting of clover, or sweet clover and legume straw after threshing the seed are plowed under in the fall before the land is seeded to corn the following spring.

The first cutting of clover or sweet clover is mowed and allowed to lie on the ground. The second growth comes up through this and is harvested for seed, the straw being returned to the plots on which it grew.

In addition to these crop residues field peas are seeded in the corn at the time of the last cultivation. The peas are not harvested, but allowed to lie on the ground and are disked under with the corn stalks the next spring when the land is prepared for oats.

In the livestock farming system all organic matter is returned in form of barnyard manure. Each plot receives a quantity of manure equal in weight to the total weight of all crops removed from that plot in the three year rotation. Because of limited funds it has not been possible to determine the moisture content of the manure nor the total weight of dry organic matter returned, nor has the manure been produced from the crop actually grown on the several plots.

It has been assumed, however, from the results obtained at other experiment stations that the weights of the manure applied, including moisture, could be produced by feeding the amounts of dry matter produced on the several plots. It is also assumed that since all of the crops, corn, oats, and legumes, are common feed crops, that the composition of the manure is approximately what it would be if the manure had been derived from the crops actually grown.

Application of Phosphorus and Potassium.—Phosphorus has been applied in the form of acid phosphate at the rate of 200 pounds per acre. This amount of phosphate is applied broadcast before the spring disking of the fall plowed land in preparation for corn planting. The same amount of phosphate is applied before disking the corn stubble or stalks before seeding oats. No phosphate is applied the year the land is in legume.

Potassium in the form of potassium chloride is applied at the rate of 200 pounds per acre in the same manner as phosphate ahead of the corn and oats crops. None is applied when the land is in legume.

Crops Grown.—The sequence of crops in this three year rotation, No. 22, is corn followed by oats followed by legumes seeded as a catch crop in the oats. In the grain farming system field peas are seeded as a catch crop at the time of the last cultivation of the corn crop.

The varieties of crops grown have been:

Corn: Brookings 86.

Oats: Swedish Select 1913-15; 60-Day 1916-37.

Legume: Field Peas, 1913; medium red clover 1914-19; white sweet clover 1920-25; Hubam sweet clover 1926; white sweet clover 1929-32; medium red clover 1933-36; soy beans 1937.

Field Peas: (Catch crop) Canadian, S. D. 14.

Yields.—In the following tables the yields of the several crops for each year grown and the average yield of each crop and of all crops for all the years grown are recorded:

Corn.—Table No. 16 reveals the fact that for the 25 years that corn was grown the average yields per acre following the several treatments were:

	Yield bu.	Increase over no treatment	Increase per cent
		bu.	
No treatment	34.87		
Crop residues	33.50	−1.37	−3.93
Crop residues and peas	34.38	−0.49	−1.41
Crop residues, peas, and phosphorus	35.01	0.14	0.40
Crop residues, peas, and potassium	35.38	0.51	1.46
Crop residues, peas, phosphorus & potassium	35.75	0.58	2.52
Manure only	37.58	2.71	7.77
Manure and phosphorus	35.76	0.89	2.55
Manure and potassium	36.27	1.40	4.01
Manure, phosphorus and potassium	34.95	0.08	0.23

The yields of corn stalks are also recorded in Table 16 and the comparative yields of corn, grain and stalks are shown graphically in Figure 19.

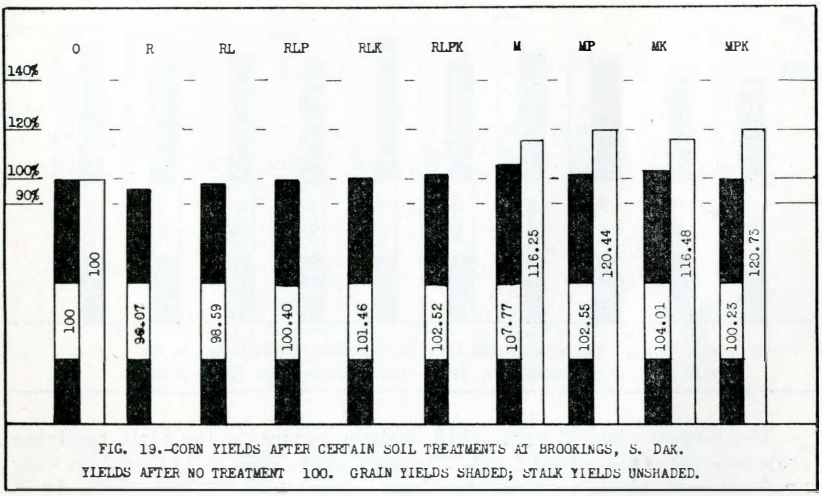

FIG. 19.—CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

The outstanding fact in the corn yields is that manure alone produced the highest yield, 37.58 bushels, which was 2.71 bushels over the yield from no treatment plots, or 7.77 per cent.

Oats.—Table No. 17 reveals the fact that for the 25 years during which oats was grown on this project the average yields per acre following the several soil treatments were as follows:

	Yield bu.	Increase over no treatment bu.	Increase per cent
No treatment	49.29		
Crop residues	50.30	1.01	2.05
Crop residues and peas	53.28	3.99	8.09
Crop residues, peas and phosphorus	55.71	6.42	13.42
Crop residues, peas and potassium	53.98	4.69	9.52
Crop residues, peas, phosphorus, and potassium	57.18	7.89	16.01
Manure only	53.13	3.84	7.79
Manure and phosphorus	54.51	5.22	10.59
Manure and potassium	52.56	3.27	6.63
Manure, phosphorus, and potassium	54.58	5.29	10.73

The yields of oat straw are also recorded in Table No. 17 and comparative yields of oats, grain and straw, are shown graphically in Figure 20.

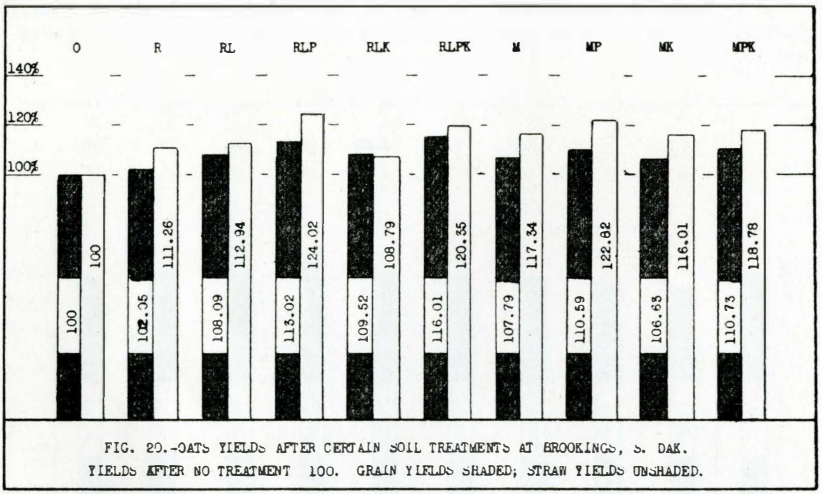

FIG. 20.-OATS YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED.

The largest yield of oats, 57.18 bushels, occurs on the plots receiving crop residues, peas, phosphorus, and potassium. This is 7.89 bushels over no treatment plots, or 16.01 per cent. The next highest yield, 55.71 bushels, follows the application of crop residues, peas, and phosphorus. This is 6.42 bushels, or 13.42 per cent, over the yield following no treatment.

Legume Seed.—Reference to Table No. 18 reveals the fact that for the 22 years during which legume seed had an opportunity to mature the average yields for all legume seed following the several soil treatments were as follows:

	Yield bu.	Increase over no treatment bu.	Increase per cent
No treatment	4.33		
Crop residues	4.28	–0.05	–1.15
Crop residues and peas	4.79	0.46	10.62
Crop residues, peas and phosphorus	4.73	0.40	9.24
Crop residues, peas and potassium	4.03	–0.30	–6.93
Crop residues, peas, phosphorus and potassium	4.16	–0.17	–3.93
Manure only	4.53	0.20	4.62
Manure and phosphorus	4.19	–0.14	–3.23
Manure and potassium	4.35	0.02	0.46
Manure, phosphorus and potassium	3.95	–0.38	–8.78

The yields of legume straw are also shown in Table No. 18 and the comparative yields of legume seed are shown graphically in Figure 21.

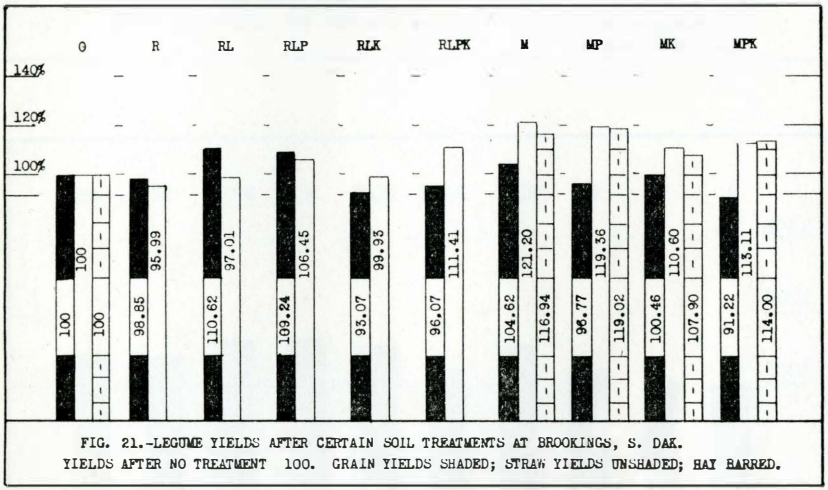

FIG. 21.-LEGUME YIELDS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK.
YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED; HAY BARRED.

Legume Hay.—Reference to Table No. 19 shows that no hay was harvested from the plots of the grain farming system and that the average yields of hay for 25 years following the several soil treatments in the livestock farming systems are as follows:

	Yield lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	1,393		
Manure alone	1,629	236	16.94
Manure and phosphorus	1,658	265	19.02
Manure and potassium	1,503	110	7.90
Manure, phosphorus, and potassium	1,588	195	14.00

The comparative yields of legume hay following the several soil treatments are shown graphically in Figure No. 21.

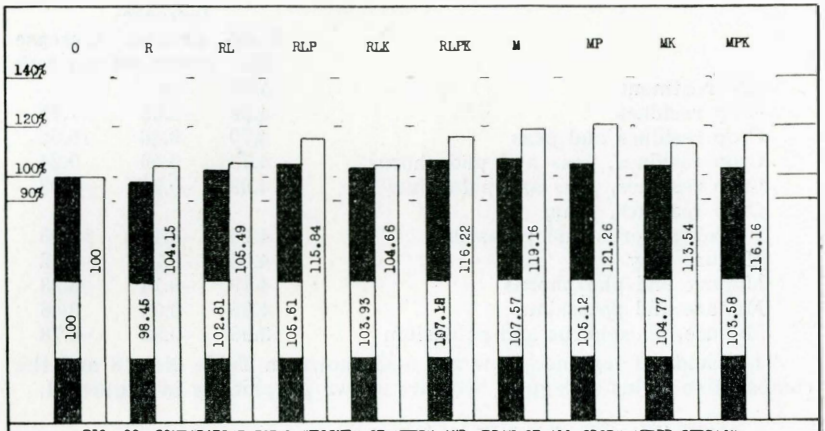

FIG. 22.-COMPARATIVE TOTAL WEIGHTS OF SEEDS AND STRAW OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW YIELDS UNSHADED.

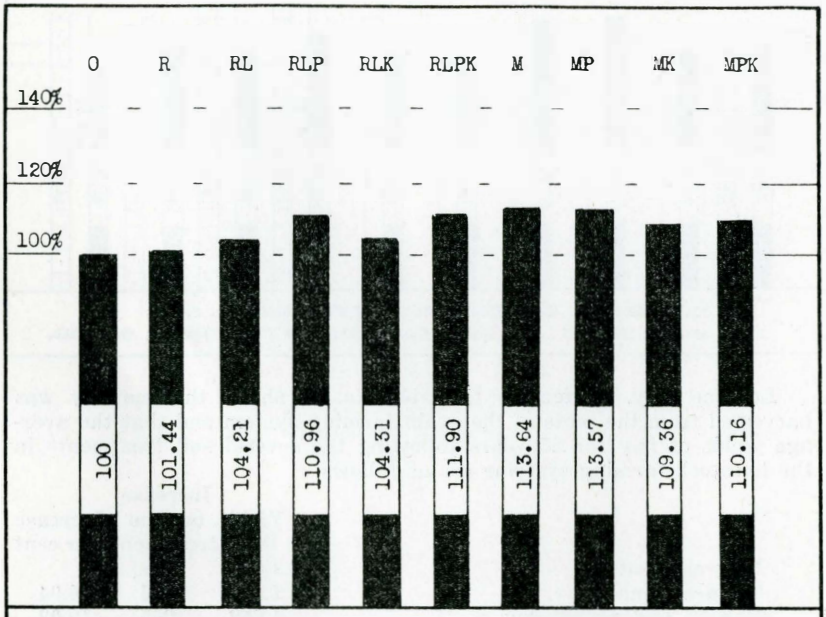

FIG. 23.-TOTAL WEIGHTS OF GRAIN AND STRAW AFTER CERTAIN SOIL TREATMENTS AT BROOKINGS, S. DAK. NO TREATMENT 100. CORN, OATS, AND LEGUMES, FOR 25 YEARS.

It will be observed that the largest average yield of legume hay, 1658 pounds, followed the application of manure and phosphorus and the increase over no treatment was 265 pounds, or 19.02 per cent. Manure alone produced only 29 pounds less. Potassium seems to have a depressing effect upon the yield wherever applied.

Precipitation.—Rainfall has varied greatly during the progress of this project. The reader who may wish to study the rainfall in relation to crop yields is referred to Plate I and Figures No. 9 and No. 10.

Summary.—Table No. 20 records the average yields for each crop for all the years it was seeded, following the several soil treatments as well as the gain or loss in yield as compared with the yield following no soil treatment.

Table No. 21 records the total average yield of all crops harvested following the several soil treatments, the average gain or loss and the average increase or decrease per cent of yield as compared with the total yield from the no treatment plots.

The comparative yields of total harvested dry matter following the several soil treatments are graphically shown in Figure No. 22 and Figure No. 23.

From the data recorded in these tables and figures the following brief summary of results may be made:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	2,992		
Crop residues	3,035	43	1.44
Crop residues and peas	3,118	126	4.21
Crop residues, peas, and phosphorus	3,320	328	10.96
Crop residues, peas, and potassium	3,121	129	4.31
Crop residues, peas, phosphorus and potassium	3,348	356	11.90
Manure only	3,400	408	13.64
Manure and phosphorus	3,398	406	13.57
Manure and potassium	3,272	280	9.36
Manure, phosphorus and potassium	3,296	304	10.16

The outstanding facts shown in this table are:

1. All applications of organic matter have been followed by total crop yields greater than the yields from soil receiving no organic matter.
2. Organic matter alone in the form of manure produced the highest yield and is more than three times as effective as organic matter applied as crop residues and peas, and more than nine times as effective as crop residues without peas plowed under.
3. The use of phosphorus with manure did not increase the yield, while the use of phosphorus with crop residues and peas plowed under increased the gain due to organic matter 2.6 times.
4. The use of phosphorus with residues and peas resulted in an increase of yield almost three times as great as that from the residues and peas alone.

5. The use of potassium with crop residues and peas was, when applied alone, only three pounds more effective than the organic matter alone, but slightly more effective than phosphorus and organic matter when applied in combination with phosphorus and organic matter.
6. Potassium when applied with manure whether alone or with phosphorus reduced the increase due to the application of manure.

Conclusion.—While it is unsafe to draw definite conclusions without a further detailed study of just what goes on in the soil in regard to the decomposition of the organic matter in the form of residues and manure and the effect on the liberation of phosphorus and potassium in the soil, it may be stated, tentatively at least, that under the conditions of this project productivity has been maintained by the addition of crop residues and peas plowed under where phosphorus has been added and that manure alone has accomplished the same result. Just what the actual trend in productivity has been, that is whether the soil is actually becoming permanently more or less productive, under the treatments, cannot be determined because of the extreme variations in rainfall, temperature, insects and plant disease from year to year while the project has been in progress.

It appears that the livestock farming system, in so far as yields are concerned, is somewhat more effective than the grain farming system.

CORN

TABLE 16.—Yields of Corn Following Certain Soil Treatments at Brookings, S. D.
Rotation No. 22

Treatment		Residues		Residue+Leg.		R+L+P		R+L+K		R+L+PK		None		Manure		Man.+P		M+K		M+PK	
Plot No.		−60		−61		−62		−63		−64		−65		−66		−67		−68		−69	
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1913	360-9	45.71		46.43		36.14		60.14		46.00		48.43	1500	55.28	1650	49.43	2000	53.14	2000	50.57	1750
1914	560-9	42.29		47.77		51.41		65.47		45.62		46.70	1200	50.05	1600	50.12	1250	52.12	1650	47.55	1450
1915	460-9	14.43		16.68		17.07		13.49		15.74		12.33	2280	14.93	2900	15.27	3020	16.04	2680	13.26	2520
1916	360-9	42.60		39.98		45.30		41.21		49.50		39.80	2400	53.41	3100	46.80	2840	40.73	3020	46.70	3040
1917	560-9	41.08		45.48		36.27		41.08		41.53		34.08	2200	38.88	2300	35.02	3000	39.36	2250	33.86	3800
1918	460-9	48.85		48.60		53.35		49.50		51.43		47.56	2200	51.43	2780	52.45	2400	54.00	2650	56.57	2750
1919	360-9	61.50		58.38		64.75		63.13		65.88		57.13	2750	66.75	4000	62.25	3900	62.88	3450	60.25	3450
1920	560-9	51.14		53.00		65.00		64.00		64.85		65.28	2600	66.00	2500	64.00	3800	59.71	2600	59.85	2900
1921	460-9	57.35		56.28		59.43		55.71		62.28		55.14	1400	59.14	1500	53.85	2100	60.43	1900	61.71	1940
1922	360-9	32.86		30.71		28.57		27.57		31.57		31.14	--	33.71	--	32.57	--	30.28	--	27.43	--
1923	560-9	51.28		49.28		54.43		53.14		58.28		56.43	2000	59.85	2500	57.57	2540	63.28	2860	57.14	2900
1924	460-9	43.57		47.14		49.28		45.71		44.43		42.00	1200	49.14	1500	48.14	1500	45.57	1400	44.28	1700
1925	360-9	25.86		30.71		32.28		32.00		36.14		40.71	1500	41.00	1600	38.14	1680	36.71	1800	31.71	1450
1926	560-9	46.54		47.29		50.24		41.56		43.65		33.33	1160	44.30	1040	49.93	1100	49.03	1380	48.78	1300
1927	460-9	33.60		33.46		34.93		25.93		29.94		30.20	2100	35.51	2800	34.51	2620	33.94	2720	34.48	3080
1928	360-9	44.28		44.28		40.86		40.00		38.00		38.57	900	36.57	1150	36.00	1040	38.57	840	42.28	1080
1929	560-9	48.29		47.14		49.43		44.29		53.14		50.29	1360	54.86	1460	53.14	1380	54.29	1400	52.86	1700
1930	460-9	18.29	2270	18.86	2620	18.57	2820	20.00	2840	17.71	2980	20.29	2480	17.57	2870	12.29	2880	13.14	2720	13.43	2720
1931	360-9	5.43	2220	5.00	1930	4.86	1260	8.57	2500	8.00	2590	10.57	2410	6.57	2040	3.43	1760	4.29	2050	4.71	2080
1932	560-9	24.14	2250	28.57	2160	20.43	2570	30.29	1720	24.57	2080	30.71	1310	24.86	1940	20.00	1820	27.71	1420	20.00	1440
1933	460-9	0.57	880	0.29	780	0.14	740	0.21	1155	0.21	945	0.07	735	0.14	600	0.71	455	0.11	643	0.21	570
1934	360-9	5.71	900	7.57	770	9.00	920	8.71	990	9.71	1270	10.43	1070	9.29	1050	8.57	1300	8.29	1320	9.86	1360
1935	560-9	22.09	1094	22.64	1295	19.69	1342	19.76	1767	19.29	1760	22.87	1649	23.91	1966	25.36	1945	22.16	2099	18.89	1508
1936	460-9	8.29		5.29		4.14		4.50		3.93		10.00	1350	8.21	1250	6.43	1600	6.21	1350	6.93	1400
1937	360-9	21.86	1105	28.71	1100	29.71	1205	28.57	1505	32.36	1495	37.78	1450	38.21	1800	38.14	1700	34.71	1805	30.43	1855
Av. 25 Yrs.		33.50		34.38		35.01		35.38		35.75		34.87		37.58		35.76		36.27		34.95	
Av. 24 Yrs.													1717		1996		2068		2000		2073
Increase over "None"		−1.37		−0.49		0.14		0.51		0.88				2.71	279	0.89	351	1.40	283	0.08	356
Increase per cent		−3.93		−1.41		0.40		1.46		2.52				7.77	16.25	2.55	20.44	4.01	16.48	0.23	20.73
Av. 7 Yrs.			1531		1522		1551		1782		1874		1587		1752		1694		1722		1648
Increase over "None"			−56		−65		−36		195		287				165		107		135		61
Increase per cent			−3.53		−4.10		−2.27		12.29		18.09				10.40		6.74		8.51		3.84

None—no treatment. R—crop residues. L—peas. M—manure. P—phosphorus. K—potassium.

OATS

TABLE 17.—Yields of Oats Following Certain Soil Treatments at Brookings, S. D.
Rotation No. 22.

Treatment		Residues		Res.+Leg.		R+L+P		R+L+K		R+L+PK		None		Manure		Man.+P		M+K		M+PK	
Plot No.		-60		-61		-62		-63		-64		-65		-66		-67		-68		-69	
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1913	460-9	44.69	1430	45.00	1330	52.50	1580	47.50	1280	51.25	1420	49.38	1370	52.19	1300	62.19	1750	53.13	1410	62.19	1760
1914	360-9	46.56	3200	42.81	2850	34.69	3500	41.25	2680	35.00	2640	45.94	2410	42.19	2690	48.75	2830	50.31	2610	55.94	3020
1915	560-9	89.69	3780	85.63	3950	76.56	4210	79.06	3820	81.89	4330	79.06	3060	80.63	3720	54.06	3690	53.13	3530	57.81	3540
1916	460-9	64.06	1850	63.13	1800	73.13	2250	64.69	1860	72.81	2310	66.89	2940	72.19	3430	69.06	2490	72.50	2340	73.13	2430
1917	360-9	95.63	2160	94.06	2040	100.31	2420	92.81	1960	106.25	2440	80.00	1900	97.81	2250	105.00	2710	97.50	2070	104.06	2570
1918	560-9	80.00	2290	88.75	2360	88.75	2010	89.06	2200	82.19	1970	61.56	1230	68.44	1810	75.31	1840	75.00	1850	66.88	1860
1919	460-9	53.13	1750	59.38	1880	64.06	2450	57.50	1810	65.00	1900	56.56	1570	59.06	1920	59.38	1930	58.75	1720	56.25	1700
1920	360-9	52.50	2050	58.75	1850	64.69	2210	61.25	1690	64.69	2230	54.37	1690	59.69	1920	60.31	1620	49.69	1460	59.38	1600
1921	560-9	47.19	1420	51.88	1450	59.06	1960	54.06	1570	57.19	1970	47.50	1330	50.00	1430	54.06	1740	50.63	1580	47.50	1590
1922	460-9	27.19	860	51.25	1710	49.69	1730	41.25	1380	50.94	1630	42.50	1170	51.56	1600	62.50	1550	57.81	1620	57.50	1500
1923	360-9	61.25	2440	63.13	2570	60.94	2400	67.81	2530	68.13	2720	66.88	1960	68.75	2420	69.06	2540	73.75	2390	80.94	2460
1924	560-9	61.56	3130	63.75	2660	64.69	2830	64.69	2630	67.19	2650	58.44	2530	59.69	2490	65.63	3600	73.13	3760	81.89	3680
1925	460-9	60.94	2450	66.88	2460	63.13	2530	77.50	2720	71.88	2600	61.56	2230	59.06	3210	47.50	3680	53.13	3300	65.31	3010
1926	360-9	28.75	2080	32.81	1890	45.31	2230	40.94	2230	52.81	2310	31.56	1290	38.13	1620	57.19	1170	34.38	1700	37.81	2090
1927	560-9	61.25	2040	67.81	2270	78.13	2500	67.50	2040	73.75	2440	45.63	1540	58.13	1940	61.56	2290	56.88	2080	59.38	2000
1928	460-9	60.94	1650	68.44	1610	69.69	1670	62.50	1100	79.06	2070	57.19	2820	70.31	2090	73.13	2060	63.44	2670	64.38	1940
1929	360-9	48.13	1560	56.88	1700	60.00	1500	62.50	1620	62.50	1440	52.50	1580	60.00	2140	65.94	1590	54.38	1060	50.63	1130
1930	560-9	63.13	1780	64.06	1850	71.25	2220	65.63	1900	70.94	2230	65.00	1440	68.13	2020	68.75	2200	68.44	1910	62.81	1990
1931	460-9	19.38	1380	19.06	1290	21.25	1420	20.94	1230	25.63	1480	21.88	950	24.06	1480	21.25	1720	23.75	1520	26.88	1600
1932	360-9	60.32	1630	63.44	1830	68.75	1940	65.63	1700	71.88	1700	66.25	1780	67.50	1840	65.00	2000	68.75	1860	74.38	1920
1933	560-9	0.94	470	0.14	95	0.18	195	0.47	235	0.47	85	1.25	310	0.63	330	0.63	280	0.94	370	0.78	275
1934	460-9	Failure due to drought. 2000 pounds Russian thistles removed from entire acre.																			
1935	360-9	54.06	1850	53.13	2000	55.00	2160	55.94	1790	57.81	1950	60.31	1650	61.56	1940	60.94	1910	63.13	1840	62.19	2020
1936	560-9	31.56	1490	28.13	1750	25.00	1850	21.88	1500	18.75	1450	23.75	1340	24.38	1570	23.13	2060	25.00	1950	21.88	1450
1937	460-9	44.69	1470	43.75	1700	45.94	1730	47.19	1690	41.56	2020	36.25	1440	34.06	1560	32.50	1760	36.56	1580	34.69	2190
Av. 25 Yrs.		50.30	1848	53.28	1876	55.71	2060	53.98	1807	57.18	1999	49.29	1661	53.13	1949	54.51	2040	52.56	1927	54.58	1973
Increase over "None"		1.01	187	3.99	215	6.42	399	4.69	146	7.89	338			3.84	288	5.22	379	3.27	266	5.29	312
Increase per cent		2.05	11.26	8.09	12.94	13.02	24.02	9.52	8.79	16.01	20.35			7.79	17.34	10.59	22.82	6.63	16.01	10.73	18.78

None—no treatment. R—crop residues. L—peas. M—manure. P—phosphorus. K—potassium.

TABLE 18.—Yields of Legume Seed and Straw Following Certain Soil Treatments at Brookings, S. D., Rotation No. 22

Treatment			Residues		Res.+Leg.		R+L+P		R+L+K		R+L+PK		None		Manure		M+P		M+K		M+PK	
Plot No.			−60		−61		−62		−63		−64		−65		−66		−67		−68		−69	
	Yield		Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
	Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
Field Peas	1913	560-9	9.83	3100	10.67	3010	11.00	3120	10.33	2920	10.33	3230	14.50	2650	14.50	2820	12.33	2870	13.50	2960	11.00	3240
R.Cl.	1914	460-9	1.08	715	1.25	885	1.33	815	1.08	885	1.08	965	1.50	1320	1.50	1490	1.58	1825	1.75	1630	1.96	1345
R.Cl.	1915	360-9	1.28	1280	1.83	1770	2.33	2180	1.70	1780	2.28	2740	1.00	1160	1.33	1540	2.50	2450	1.67	1640	2.58	2060
R.Cl.	1916	560-9	1.92	2180	2.62	2420	2.70	3140	3.17	2430	2.58	2730	2.33	1460	2.70	1780	2.95	1930	3.12	1740	2.67	1750
R.Cl.	1917	460-9	0	800	0	800	0	1200	0	1200	0	1200	0	410	0	1050	0	1250	0	820	0	1000
R.Cl.	1918	360-9	No seed matured. Both cuttings for hay.											2600		2900		2000		2250		1950
R.Cl.	1919	560-9		4000		4100		4460		4440		4600		3300		3700		3800		3900		3180
S.Cl.	1920	460-9	460-4 Sweet Clover died after cutting first time.										0.83	1450	0.92	1685	0.83	1200	0.83	1400	0.92	2095
S.Cl.	1921	360-9	4.50	1030	6.50	1230	8.33	1620	6.83	1330	9.83	2110	8.33	1400	10.17	1690	7.17	2210	11.67	2500	9.00	2360
S.Cl.	1922	560-9	15.00	3000	14.17	2650	14.83	2760	11.67	2300	13.00	2070	10.33	1930	10.50	1820	10.17	1890	8.83	1920	9.17	2050
S.Cl.	1923	460-9	19.00	3300	21.83	3630	18.83	3410	15.00	3640	13.83	3310	10.83	3090	13.17	4410	12.50	3650	14.33	3140	10.50	3470
S.Cl.	1924	360-9	17.83	3730	24.17	3850	24.50	4330	21.33	4720	20.83	4550	19.00	3860	17.50	4550	18.00	4320	18.17	4510	19.50	4630
S.Cl.	1925	560-9	No seed harvested. Plots plowed immediately after first cutting to control perennial pepper grass.																			
S.Cl.	1926	460-9	Seeded to hubam, annual sweet clover. Pepper grass so thick plots disked and harrowed May 24.																			
S.Cl.	1927	360-9	No record of any seed crop.																			
S.Cl.	1928	560-9	Plowed under May 21 on account of pepper grass.																			
S.Cl.	1929	460-9	6.00	2330	4.58	2020	2.92	2390	3.17	2360	3.83	1980	6.33	2310	6.17	2740	7.17	2120	5.83	1750	5.50	1750
S.Cl.	1930	360-9	0.67	900	1.17	1250	0.92	1130	1.25	1300	1.33	1410	1.50	1470	2.67	1820	2.50	1670	2.00	1450	0.67	1700
S.Cl.	1931	560-9	6.08	2120	5.17	1900	2.92	1220	2.75	1760	1.58	1820	1.83	1200	1.08	1910	0.33	1750	0.33	1770	0.17	1540
R.Cl.	1932	460-9	3.50	1490	2.83	1040	2.50	1320	1.67	830	2.00	1100	6.67	1000	5.17	1040	3.00	1700	2.50	860	3.33	1170
S.Cl.	1933	360-9	0.67	710	0.75	655	1.17	930	0.83	85	1.33	1520	3.00	1220	3.83	1970	3.00	1520	2.83	1030	3.00	920
R.Cl.	1934	560-9	Complete failure due to drought; seeded to Bison flax, also complete failure.																			
SoyB.	1935	460-9	Red Clover failed—seeded to soy beans, cut for hay.																			
R.Cl.	1936	360-9	Mostly Sweet Clover; no yield due to drought.																			
SoyB.	1937	560-9	6.75	395	7.92	205	9.67	450	7.83	380	7.75	735	7.33	560	8.42	325	8.25	505	8.25	535	6.92	415
Av. All Crops 22 Yrs.			4.28	1413	4.79	1428	4.73	1567	4.03	1471	4.16	1640	4.33	1472	4.53	1784	4.19	1757	4.35	1628	3.95	1665
Increase over "None"			−0.05	−59	0.46	−44	0.40	95	−0.30	−1	−0.17	168			0.20	312	−0.14	285	0.02	156	−0.38	193
Increase per cent			−1.15	−4.01	10.62	−2.99	9.24	6.45	−6.93	−0.07	−3.93	11.41			4.62	21.20	−3.23	19.36	0.46	10.60	−8.78	13.11
Av. R.Cl. 11 Years			0.71	951	0.78	1001	0.81	1192	0.69	1051	0.72	1212	1.05	1023	0.97	1227	0.91	1360	0.82	1167	0.96	1132
Increase over "None"			−0.34	−72	−0.27	−22	−0.24	169	−0.36	28	−0.33	189			−0.08	204	−0.14	337	−0.23	144	−0.09	109
Increase per cent			−32.38	−7.04	−25.71	−2.15	−22.86	16.52	−31.29	2.74	−31.43	18.48			−7.62	19.94	−13.33	32.94	21.90	14.08	−8.57	10.65
Av. S.Cl. 10 Years			6.98	1758	7.83	1719	7.44	1829	6.28	1750	6.56	1877	6.20	1793	6.60	1960	6.17	2033	6.48	1947	5.84	2052
Increase over "None"			0.78	−35	1.63	−74	1.24	36	0.08	−43	−0.36	84			0.40	167	−0.03	240	0.28	154	−0.36	259
Increase per cent			12.58	−1.95	26.29	−4.13	20.00	2.01	1.29	−2.40	−5.81	4.68			6.45	9.31	−0.48	13.39	4.52	8.59	−5.81	14.45

NOTE.—The minus (−) sign indicates decrease. None—no treatment. R—crop residues. L—peas. M—manure. P—phosphorus. K—potassium.

LEGUMES

TABLE 19.—Yields of Legume Hay Following Certain Soil Treatments at Brookings, S. D.
Rotation No. 22

Crop	Year	Treatment Plot No. Yield Acre	Residues -60 Hay	Res.+Leg. -61 Hay	R+L+P -62 Hay	R+L+K -63 Hay	R+L+PK -64 Hay	None -65 Hay	Manure -66 Hay	M+P -67 Hay	M+K -68 Hay	M+PK -69 Hay
Field Peas	1913	560-9					Cut for seed.					
R.Cl.	1914	460-9						2240	2190	3190	1940	2730
R.Cl.	1915	360-9						830	1230	2670	1360	2930
R.Cl.	1916	560-9						1750	2730	3140	2840	360
R.Cl.	1917	460-9						980	1220	1780	1520	1800
R.Cl.	1918	360-9						650	810	600	650	800
R.Cl.	1919	560-9						500	560	1000	700	450
S.Cl.	1920	460-9						1950	1760	2310	1980	2150
S.Cl.	1921	360-9						3120	3320	3900	3800	3660
S.Cl.	1922	560-9					One cutting for seed only.					
S.Cl.	1923	460-9					No hay harvested. One cutting for seed only.					
S.Cl.	1924	360-9						2810	3310	2720	3300	3310
S.Cl.	1925	560-9						2640	2960	3640	3660	3800
S.Cl.	1926	460-9		Seeded to hubam, annual sweet clover. Pepper grass so thick plots disked and harrowed May 24.								
S.Cl.	1927	360-9						1360	1500	840	900	820
S.Cl.	1928	560-9					Plowed under May 21 on account of pepper grass.					
S.Cl.	1929	460-9						3720	4840	4000	4040	4020
S.Cl.	1930	360-9						1600	2200	2050	1800	900
S.Cl.	1931	560-9						1560	1640	900	760	740
R.Cl.	1932	460-9						3800	3800	3700	3400	5100
S.Cl.	1933	360-9						460	595	610	615	630
R.Cl.	1934	560-9					Complete failure due to drought. Seeded to Bison flax, also complete failure.					
S.Bn.	1935	460-9	Red Clover failed, soy beans seeded; did not mature; cut for hay.					1200	2400	1800	2200	3200
R.Cl.	1936	360-9						3650	3660	2600	2100	2300
S.Bn.	1937	560-9	Red Clover failed. Seeded to soy beans. Cut for seed.									
Av. All Crops 25 Yrs.			No hay removed from Plots -60 to -64. Grain farming.					1393	1629	1658	1503	1588
Increase over "None"								--	236	265	110	195
Increase per cent								--	16.94	19.02	7.90	14.00
Av. Red Clover 11 Yrs.								1309	1473	1698	1319	1497
Increase over "None"								--	164	389	10	188
Increase per cent								--	12.53	29.72	0.76	14.36
Av. Sw. Clover 13 Yrs.								1478	1702	1613	1604	1541
Increase over "None"								--	224	135	126	68
Increase per cent								--	15.16	9.13	8.53	4.26

NOTE.—The minus (-) sign indicates decrease. None—no treatment. R—crop residues. L—peas. M—manure. P—phosphorus. K—potassium.

SUMMARY

TABLE 20.—Summary of the Results From All Soil Treatments in All Crops—Corn, Oats, Legumes—in Rotation No. 22 at Brookings, S. D., Expressed as Weighted Averages

Crop / No. of Yrs. / Treatment	Corn-Grain 25 Yield Bu.	Corn-Grain 25 Gain Bu.	Corn-Stalks 24 Yield Lbs.	Corn-Stalks 24 Gain Lbs.	Oats-Grain 25 Yield Bu.	Oats-Grain 25 Gain Bu.	Oats-Straw 25 Yield Lbs.	Oats-Straw 25 Gain Lbs.	Legume-Seed 22 Yield Bu.	Legume-Seed 22 Gain Bu.	Legume-Straw 22 Yield Lbs.	Legume-Straw 22 Gain Lbs.	Legume-Hay 25 Yield Lbs.	Legume-Hay 25 Gain Lbs.
None	34.87		1717		49.29		1661		4.33		1472		1393	
Residues	33.50	−1.37			50.30	1.01	1848	187	4.28	−0.05	1413	−59		
Res. +Leg.	34.38	−0.49	Stalks		53.28	3.99	1876	215	4.79	**0.46**	1428	−44		Hay
R.+L.+P.	35.02	0.14	not		55.71	6.42	2060	**399**	4.73	0.40	1567	95		not
R.+L.+K.	35.38	0.51	Removed		53.98	4.69	1807	146	4.03	−0.30	1471	−1		Removed
R.+L.+PK.	35.75	0.88			57.18	**7.89**	1999	338	4.16	−0.17	1640	168		
Manure	37.58	**2.71**	1996	279	53.13	3.84	1949	288	4.53	0.20	1784	**312**	1629	236
M.+P.	35.76	0.89	2068	351	54.51	5.22	2040	379	4.19	−0.14	1757	285	1658	**265**
M.+K.	36.27	1.40	2000	283	52.56	3.27	1927	266	4.35	0.02	1628	156	1503	110
M.+ PK.	34.95	0.08	2073	**356**	54.58	5.29	1973	312	3.95	−0.38	1665	193	1588	195

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Residues	−3.93		2.05	11.26	−1.15	−4.01	
Res. +Leg.	−1.41	Stalks	8.09	12.94	**10.62**	−2.99	Hay
R.+L.+P.	0.40	not	13.02	**24.02**	9.24	6.45	not
R.+L.+K.	1.46	Removed	9.52	8.79	−6.93	−0.07	Removed
R.+L.+PK.	2.52		**16.01**	20.35	−3.93	11.41	
Manure	7.77	16.25	7.79	17.34	4.62	**21.20**	16.94
M.+P.	2.55	20.44	10.59	22.82	−3.23	19.36	**19.02**
M.+K.	4.01	16.48	6.63	16.01	0.46	10.60	7.90
M.+PK.	0.23	**20.73**	10.73	18.78	−8.78	13.11	14.00

NOTE.—The minus (−) sign indicates decrease.
The figures indicating the greatest increase in yield in each crop are printed in bold face type.

GENERAL SUMMARY

TABLE 21.—General Summary of the Results From All Soil Treatments on All Comparable Crops: Corn, Oats, Legumes, in Rotation No. 22 Expressed in Terms of Average Yields of Grain and Straw in Pounds of Grain per Year per Acre

Treatment / Crop	Residues Grain Lbs.	Res.+ Leg. Grain Lbs.	R.+ L.+P. Grain Lbs.	R.+ L.+K. Grain Lbs.	R.+L. +PK. Grain Lbs.	None Grain Lbs.	Manure Grain Lbs.	M.+P. Grain Lbs.	M.+K. Grain Lbs.	M.+ PK. Grain Lbs.
Av. Yield Corn Grain	2345	2407	2451	2477	2503	2441	2631	2503	2539	2447
Av. Yield Oats Grain	1610	1705	1783	1727	1830	1577	1700	1744	1682	1747
Av. Yield Legume Seed	257	287	284	242	250	260	272	251	261	237
Av. Yield Total Grain (3 acres)	4212	4399	4518	4446	4583	4278	4603	4498	4482	4431
Av. Yield Total Grain (1 acre)	1404	1466	1506	1482	1528	1426	1534	1419	1494	1477
Av. Increase over "None"	−22	40	80	56	102	--	108	73	68	51
Increase per cent	−1.55	2.81	5.61	3.93	7.15	--	7.57	5.12	4.77	3.58
Av. Yield Legume Straw	1413	1428	1567	1471	1640	1472	1784	1757	1628	1665
Av. Yield Oats Straw	1848	1876	2060	1807	1999	1661	1949	2040	1927	1973
Av. Yield Total Straw (2 acres)	3261	3304	3627	3278	3639	3133	3733	3797	3555	3638
Av. Yield Total Straw (1 acre)	1631	1652	1814	1639	1820	1566	1866	1899	1778	1819
Av. Increase over "None"	65	86	248	73	254	--	300	333	212	253
Increase per cent	4.15	5.49	15.84	4.66	16.22	--	19.16	21.26	13.54	16.16
Total Av. Grain & Straw (1 acre)	3035	3118	3320	3121	3348	2992	3400	3398	3272	3296
Av. Increase over "None"	43	126	328	129	356	--	408	406	280	304
Increase per cent	1.44	4.21	10.96	4.31	11.90	--	13.64	13.57	9.36	10.16

None—no treatment. R—crop residues. L—peas. M—manure. P—phosphorus. K—potassium.

NOTE.—The minus (−) sign indicates decrease.
Since corn stalks and legume hay were not removed for the entire period in the grain farming system, no comparison of yields for these materials can be made.

PRECIPITATION RECORD, COTTONWOOD, S.D

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1910	0.66	0.07	0.76	1.06	2.54	1.30	1.11	0.48	0.82	0.32	0.53	0.30	9.95
1911	.05	.60	T	.85	1.10	.64	.59	2.41	3.59	1.15	.72	.61	12.31
1912	.87	.05	.30	3.32	1.19	.95	2.42	3.44	1.30	.11	T	.12	14.07
1913	.18	.10	.43	1.15	2.95	.59	.81	1.84	1.15	.76	.14	.38	10.48
1914	.03	1.18	.35	2.26	2.35	1.64	1.04	1.88	1.19	2.23	.02	.84	15.01
1915	.39	1.57	.64	2.80	6.91	4.79	4.59	2.51	2.42	.90	T	.10	27.62
1916	.40	.02	.29	.82	3.87	1.83	1.80	2.22	.18	.57	.15	.14	12.29
1917	1.45	.40	.31	1.98	3.30	.62	.90	2.00	1.17	.14	.39	.50	13.16
1918	.33	.15	.34	2.27	2.78	1.37	2.29	3.43	1.43	.28	.11	.25	15.03
1919	.04	.29	.71	3.75	1.29	4.97	1.55	.20	.25	2.03	.71	.20	15.99
1920	.27	.54	.58	2.80	5.53	4.02	.67	1.87	1.63	.93	.36	.18	19.38
1921	.17	.10	.17	.40	2.91	.78	3.58	1.10	.41	.78	.29	.21	10.90
1922	.94	.32	.00	1.25	2.87	5.43	6.48	.72	.16	.92	2.72	.60	22.41
1923	.10	T	.31	.73	2.41	4.87	5.28	3.08	3.05	1.89	.18	.40	22.30
1924	T	.53	.32	.06	.29	3.03	1.78	1.48	1.00	.85	.31	1.57	11.22
1925	.40	.50	.17	1.17	.72	4.80	.60	.39	.49	.58	.13	.50	10.45
1926	.90	.10	.20	.75	2.77	1.97	3.52	1.56	.37	1.12	.16	.10	13.52
1927	.20	.11	.73	5.54	5.16	3.26	2.38	2.21	.63	T	.40	.40	21.02
1928	.03	.13	.86	.35	1.14	3.85	3.11	.94	1.65	1.19	.77	.04	14.06
1929	.46	.04	2.68	2.51	2.20	3.56	1.74	.89	1.44	1.43	.90	.30	18.15
1930	.55	.64	.61	3.59	1.85	.94	.99	7.82	1.20	3.98	.85	.05	23.07
1931	.10	.05	2.03	.17	1.27	.62	.84	.82	1.65	.71	.50	.82	9.58
1932	.40	.20	.40	3.67	3.60	4.34	2.35	.74	.26	1.21	T	.10	17.27
1933	.24	.30	1.68	2.72	4.65	.56	.43	3.14	.32	.03	.27	.19	14.53
1934	.38	.20	1.15	.39	.45	4.69	1.01	1.35	.26	1.41	.50	.20	11.99
1935	.25	.48	.85	3.65	3.60	1.68	2.76	1.08	.06	.11	.24	.92	15.68
1936	1.40	.52	.45	1.17	.70	.08	.08	.60	.79	.32	.80	.22	7.13
1937	.21	.12	1.80	.79	2.52	3.40	4.29	.21	.75	.17	.05	.34	14.65
AV.	.41	.33	.68	1.86	2.60	2.52	2.11	1.80	1.06	.93	.44	.38	15.115

T indicates trace of precipitation, less than.01.inch.

Plate II.—The Monthly and Annual Precipitation at Cottonwood, S. D.

Part II
Soil Fertility Investigations at Cottonwood, S. D.
Complete Fertility Test

Introduction.—The results here reported from the complete fertility tests have been obtained from a project carried on at the Cottonwood substation. The project has been supported by funds appropriated biennially by the South Dakota Legislature.

History.—The project was begun in 1912 and was in progress until 1936, a period of 25 years, when it was suspended on account of lack of funds to pursue it further.

Object.—Since, when the project began, nothing was known of the plant food requirements of the soils in that part of the state (see map on page 3) it was thought that long continued trials with the application of plant food elements would result in information that would form the basis for soil treatment practices which would maintain the plant food supply in the soil and make possible large crop yields.

Plan of the Work.—The project was located on three "blocks" of land on the "North Farm" each of which was divided into 10 plots two rods wide and eight rods long containing one-tenth of an acre. The plots are separated by alleys four feet in width which have been kept clear of weeds by frequent cultivation. The blocks of 10 plots each are separated by roads 20 feet in width.

The general plan of the plots, as well as their numbers and fertility treatments applied, is shown in Figure 24.

The original plan of the project has been carried out with the exception of the substitution of certain crops for the regular crops which is indicated in the tables of crop yields. It was also necessary to suspend potassium applications during the Great War.

Soil.—The soil on which the plots are situated was classified as Orman clay in the report of the "Reconnaissance Survey of the Soils of Western South Dakota" made by the Bureau of Soils of the United States Department of Agriculture in cooperation with the South Dakota Agricultural Experiment Station.

The Orman clay on the Cottonwood Experiment Farm consists of 6 to 10 inches of grayish brown silty clay to clay, underlain by a grayish brown to drab clay, which extends to a depth of several feet. It consists of material which has been washed down from the adjacent Pierre clay soils and deposited along the bottom land of Cottonwood creek. The soil lies on a nearly level terrace about 20 feet above the level of Cottonwood creek.

Orman clay is a very sticky soil when wet and when it is dry the surface breaks into fine granules. During periods of dry weather large cracks extend to a depth of three or four feet.

This soil contains less organic matter and nitrogen than the darker soils of eastern South Dakota. The average nitrogen content of 90 soil samples taken soon after the experiment substation was established in 1907 was 0.115 per cent or 2,300 pounds of nitrogen in a layer of soil seven inches deep over an acre.

Crop Rotation.—In this project the crop rotation is designated as Cottonwood No. 3 and consists of corn, wheat, and legume following each other in the order named.

0	111
N	112
P	113
K	114
0	115
NP	116
NK	117
PK	118
NPK	119
0	120

0	211
N	212
P	213
K	214
0	215
NP	216
NK	217
PK	218
NPK	219
0	220

0	311
N	312
P	313
K	314
0	315
NP	316
NK	317
PK	318
NPK	319
0	320

ROTATION NO. 3.

CORN-WHEAT-LEGUME: SOIL FERTILITY TEST.

EXPERIMENT SUBSTATION, COTTONWOOD, S.D.

Fig. 24.—Plan of the Complete Fertility Plots at the Experiment Substation at Cottonwood

The letters indicate the kind of fertilizer applied to the several plots:
O means nothing applied; often referred to as "No Treatment" or "None."
N means nitrogen applied in nitrate of soda at the rate of 350 pounds per acre.
P means phosphorus applied in acid phosphate at the rate of 200 pounds per acre.
K means potassium applied in potassium chloride at the rate of 200 pounds per acre.
Each letter has a uniform meaning whether it occurs alone or in combination with other letters.

The varieties of crops grown have been as follows:

Corn—Minnesota 13, 1912; Brookings 86, 1913-14; Highmore 86 1915-17; Alta 1095, 1918-36.

Wheat—Red Fife S. D. 67, 1912-13; Preston S. D. 67, 1914-15; Kubanka 75, 1916-19; Acme 284, 1920-24; Mindum 1935-36.

Legume—Peas S. D. 14, White Sweet Clover S. D. 190.

Soil Preparation.—The soil is fall plowed to a depth of 7 inches before the corn crop. The soil is usually dry and breaks into clods when plowed but the effect of the weather is to break these clods into smaller granules before spring when the disk and harrow are used to form a suitable seed bed.

The corn stubble is allowed to stand over winter and is then prepared for seeding wheat the spring of the second year by using a disk and harrow.

Sweet clover has been the legume crop for 21 years and is seeded with the wheat. When soy beans or peas were grown the land was usually spring plowed.

Plant Food Applications.—No organic matter has been returned to the soil except the crop stubbles.

Phosphorus is applied in the form of acid phosphate at the rate of 200 pounds per acre. Potassium is applied in the form of potassium chloride at the rate of 200 pounds per acre. Nitrogen is applied in the form of nitrate of soda at the rate of 300 pounds per acre.

Applications of nitrogen, phosphorus, and potassium are made broadcast on the soil in the spring before disking preceding the corn crop and wheat crop. No applications are made the year the legume is grown.

Reference to Figure 24 shows that each element of plant food is applied alone and in all combinations with the other two.

Harvesting Crops.—All plots are harvested and threshed separately and the yield of seed, grain, straw, and hay carefully weighed and permanently recorded.

Yields.—In the following tables the yields of the several crops for each year grown and the average yields for each crop and for all crops for the entire period of 25 years are recorded. A careful study of these data will reveal many facts not included in this necessarily brief discussion.

Corn—Table No. 22 is a record of all corn yields and shows that for the 25-year period the average yields of corn following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	8.78		
Nitrogen	8.94	0.16	1.82
Phosphorus	8.33	–0.45	–5.13
Potassium	9.13	0.35	3.99
Nitrogen and phosphorus	7.97	–0.81	–9.23
Nitrogen and potassium	9.37	0.59	6.72
Phosphorus and potassium	8.66	–0.12	–1.37
Nitrogen, phosphorus, and potassium	7.99	–0.79	–9.00

The minus sign (–) indicates decrease.

The average yields are all small and do not vary greatly. Four observations may, however, be made:

1. Nitrogen where applied alone increased the yield over that of the plots receiving no treatment 1.82 per cent.
2. Potassium where applied alone increased the yield 3.99 per cent.
3. Nitrogen and potassium together increased the yield 6.72 per cent.
4. Phosphorus whether applied alone or in combination with nitrogen, potassium, or nitrogen and potassium was followed by a yield less than that produced on the plots receiving no treatment.

No explanation is offered but however significant these differences in yield may be they are at least consistent.

The average yields of corn stalks, or stover, are also recorded in Table No. 22. The comparative yields of corn and stalks are shown graphically in Figure 25.

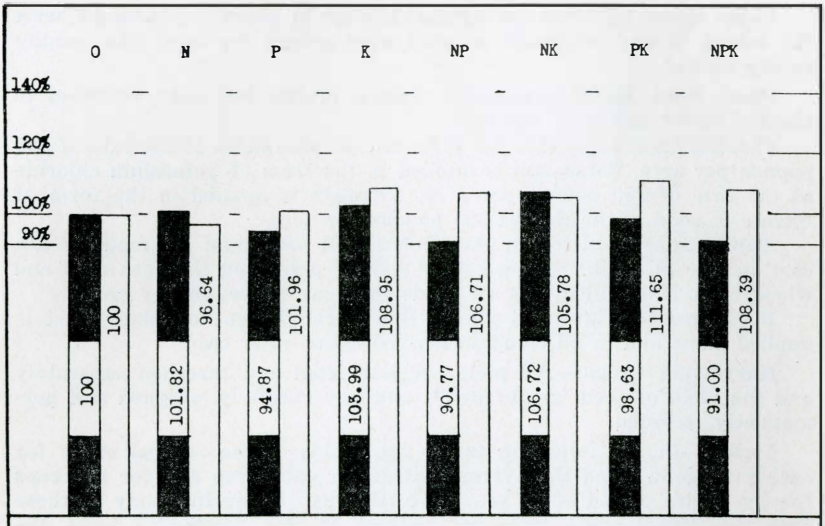

FIG. 25.–CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT COTTONWOOD, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALKS UNSHADED.

Wheat—Table No. 23 is a record of all wheat yields and shows that for the 24 years during which wheat was grown the average yields following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	9.07		
Nitrogen	7.82	–1.25	–13.78
Phosphorus	9.11	0.04	0.44
Potassium	9.73	0.66	7.28
Nitrogen and phosphorus	8.11	–0.96	–10.58
Nitrogen and potassium	8.87	–0.20	–2.21
Phosphorus and potassium	9.92	0.85	9.37
Nitrogen, phosphorus, and potassium	8.52	–0.55	–6.06

The minus sign (–) indicates decrease.

The average yields are all relatively small and do not vary greatly. These observations may, however, be made:

1. Nitrogen whether applied alone or in any combination was followed by a yield less than that obtained from the plots receiving no treatment.
2. Phosphorus when applied alone was followed by a yield 0.44 per cent larger than the yield after no treatment.
3. Potassium when applied alone was followed by an increase in yield of 7.28 per cent over no treatment.
4. Phosphorus and potassium together gave an increase of 9.37 per cent over no treatment.

As in the case of the corn crop, of the three elements applied singly, potassium, gave the largest increase in yield of wheat, but unlike the yield of corn which was greatest after nitrogen applied with potassium, the average yield of wheat is greatest following potassium applied with phosphorus.

No claim is made as to the significance of these small differences in yield of wheat following the different soil treatments, but they are at least consistent.

The average yields of wheat straw following the several soil treatments are also recorded in Table 23 and the comparative yields of grain and straw are shown graphically in Figure No. 26.

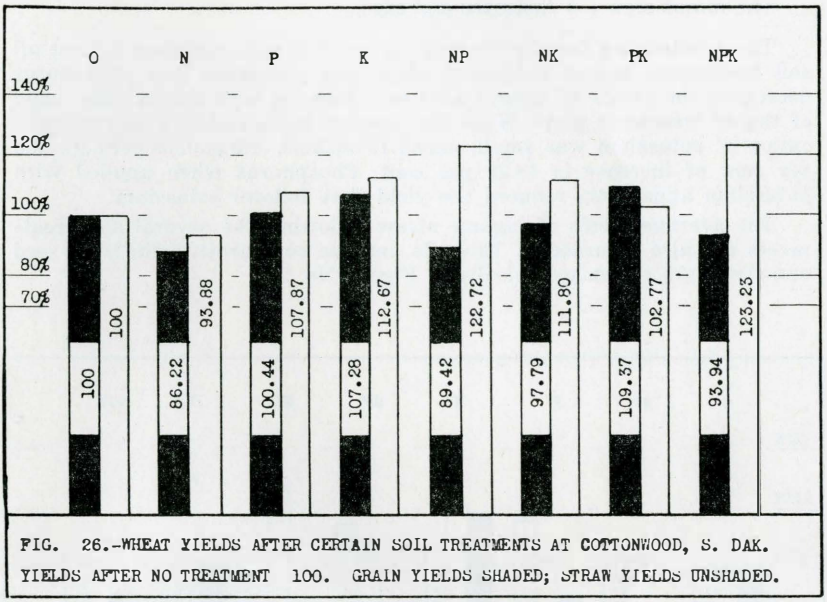

FIG. 26.-WHEAT YIELDS AFTER CERTAIN SOIL TREATMENTS AT COTTONWOOD, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED.

Legumes.—1. Seed Crop. The production of legume seed at Cottonwood has been uncertain. Table No. 24 is a record of all the yields of legume seed and straw. During the first three years of the project, 1912-1914, field peas were planted. After that time sweet clover was the legume regularly seeded. Sweet clover failed in 1926 on account of drought. Soy beans were then seeded but were destroyed by hail. In most years when the first cutting of sweet clover was removed for hay there was no seed crop, second cutting, to harvest. When the first growth of sweet clover was allowed to mature seed as in 1921, 1922 and 1923, there was of course, no hay crop. In 1916, 1927, 1928 and 1929 both cuttings were for hay.

From the record in Table No. 24 the average yields of all legume seed following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	0.82		
Nitrogen	0.55	–0.27	–32.93
Phosphorus	0.75	–0.07	–8.54
Potassium	0.97	0.15	18.29
Nitrogen and phosphorus	0.70	–0.12	–14.63
Nitrogen and potassium	0.72	–0.10	–12.20
Phosphorus and potassium	0.83	0.01	1.22
Nitrogen, phosphorus, and potassium	0.70	–0.12	–14.63

The minus sign (–) indicates decrease.

The outstanding fact in the data recorded in this summary is that all soil treatments except potassium alone and potassium and phosphorus decreased the yields of legume seed as compared with the average yield of the no treatment plots. While the average increase following the application of potassium was small, only 0.15 bushels, or 9 pounds per acre, the per cent of increase is 18.29 per cent. Phosphorus when applied with potassium apparently reduced the yield that follows potassium.

The average yields of legume straw following the several soil treatments are also recorded in Table 24 and the comparative yields of seed and straw are shown graphically in Figure No. 27.

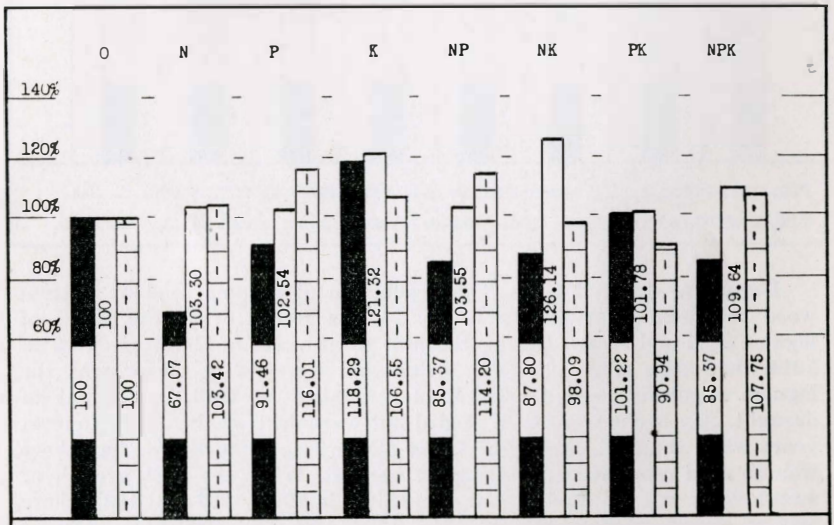

FIG. 27.–LEGUME YIELDS AFTER CERTAIN SOIL TREATMENTS AT COTTONWOOD, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW UNSHADED; HAY BARRED

2. Legume Hay.—Table No. 25 is the record of the yields of hay crops. All of the hay is from legume crops except in 1915 and 1918 when the yields are from peas and oats seeded together. There were several failures of sweet clover due to drought and in several years the sweet clover was allowed to go to seed and no hay crop was harvested.

The average yields for all hay crops for 25 years following the several soil treatments were as follows:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	993		
Nitrogen	1,027	34	3.42
Phosphorus	1,151	159	16.01
Potassium	1,058	65	6.55
Nitrogen and phosphorus	1,134	141	14.20
Nitrogen and potassium	974	–19	–1.91
Phosphorus and potassium	903	–90	–9.06
Nitrogen, phosphorus, and potassium	1,070	77	7.75

The minus sign (–) indicates decrease.

The average yields of hay following the several soil treatments are shown graphically in Figure 27.

It will be noted that the average yield of hay from the plots receiving no treatment has been approximately one half ton per acre, 993 pounds. The largest increase, 159 pounds, or 16.01 per cent, followed the application of phosphorus alone with 14.20 per cent.

Precipitation.—Plate II is a record of the monthly and annual precipitation from 1910 to 1937—28 years—at Cottonwood. See page 56.

Figure 30 shows graphically the annual precipitation at Cottonwood, S. D., for the same period. The average annual rainfall, including melted snow, is 15.115 inches and the total precipitation for the entire period is 35 feet 3.22 inches. Figure 31 shows graphically the average monthly precipitation for the same time.

A study of these data in connection with the crop yields will reveal many interesting facts which need not be repeated in this discussion.

One inch of rainfall over one acre weighs 226,350 pounds. Knowing the weight of dry matter produced per acre under a certain number of inches of rainfall it is possible to compute the efficiency of the rainfall in producing a pound of dry matter.

During the period of the project 1912 to 1936 the average annual precipitation was 15.456 inches, and the total weight of the average rainfall was 3,498,466 pounds per acre.

The number of pounds of water required to produce a pound of dry matter in the several crops grown on plots receiving no soil treatment is as follows:

Kind of Crop Grown Including Grain, Straw or Stalks or Hay	Average Yield Total Dry Matter per Acre per Year	Pounds of Water to Produce One Pound Dry Matter
Corn	1,687.6 lbs.	2,073
Wheat	1,917.2	1,825
Legume	1,436.2	2,436
Average All Crops	1,677.0	2,086

Fig. 30.—The Annual Precipitation at Cottonwood, S. D.

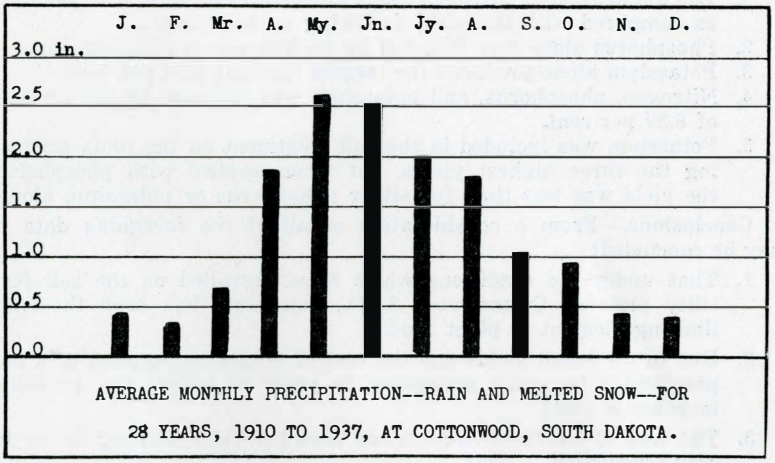

Fig. 31.—The Average Precipitation by Months at Cottonwood, S. D.

Summary.—Table No. 26 is a record of the average yield per acre for each crop for the 25-year period following the several soil treatments as well as the gain or loss in yield as compared with the yields from plots receiving no soil treatment.

Table No. 27 records the total average yield for all crops following the several soil treatments, the average gain or loss, and the average increase or decrease per cent of yields as compared with the total yield from the no treatment plots.

The comparative yields of all dry matter harvested following the several soil treatments are shown graphically in Figure No. 28 and Figure 29.

From the data recorded in these tables and figures the following brief summary may be made:

	Average Yield Total Dry Matter per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	1,677		
Nitrogen	1,619	–58	–3.48
Phosphorus	1,766	88	5.25
Potassium	1,841	164	9.74
Nitrogen and phosphorus	1,815	138	8.22
Nitrogen and potassium	1,787	110	6.55
Phosphorus and potassium	1,718	41	2.41
Nitrogen, phosphorus, and potassium	1,818	141	8.39

The minus sign (–) indicates decrease.

The average yields of total dry matter per acre for the 25-year period, 1912 to 1936, are all less than one ton per acre, and the yields following the several soil treatments do not vary greatly. It may be noted, however, that:

1. The application of nitrogen alone decreased the yield 3.48 per cent as compared with the yield following no treatment.
2. Phosphorus alone was followed by an increase of 5.25 per cent.
3. Potassium alone produced the largest increase 9.74 per cent.
4. Nitrogen, phosphorus, and potassium was followed by an increase of 8.39 per cent.
5. Potassium was included in the soil treatment on the plots producing the three highest yields, but when applied with phosphorus the yield was less than for either phosphorus or potassium alone.

Conclusions.—From a consideration of all of the foregoing data it may be concluded:

1. That under the conditions which have prevailed on the soil fertility plots at Cottonwood, S. D., potassium has been the first limiting element in plant food.
2. Due to the small yields and the cost of potassium applied it is not practicable to apply potassium in order to secure the probable increase in yield.
3. The lack of sufficient rainfall has been the chief limiting factor in crop production.
4. The average yield of total dry matter under the several soil treatments for this rotation varies from 1,619 pounds to 1,818 pounds. The recognition of the fact that the total yield of crop per acre over a period of 25 years is not likely to exceed or fall below these figures should serve as a basis for formulating farm programs in the region concerned.

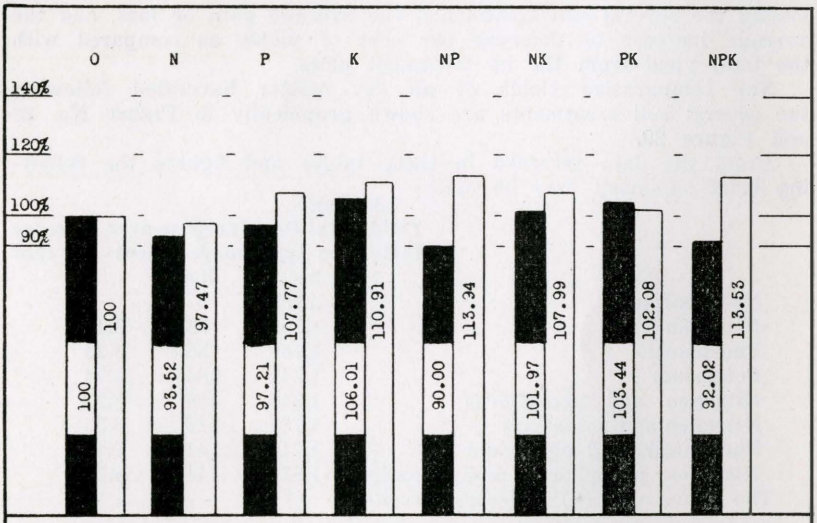

FIG. 28.-COMPARATIVE TOTAL WEIGHTS OF SEEDS, AND STRAW, STALKS, AND HAY OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT COTTONWOOD, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW, STALKS, AND HAY YIELDS UNSHADED.

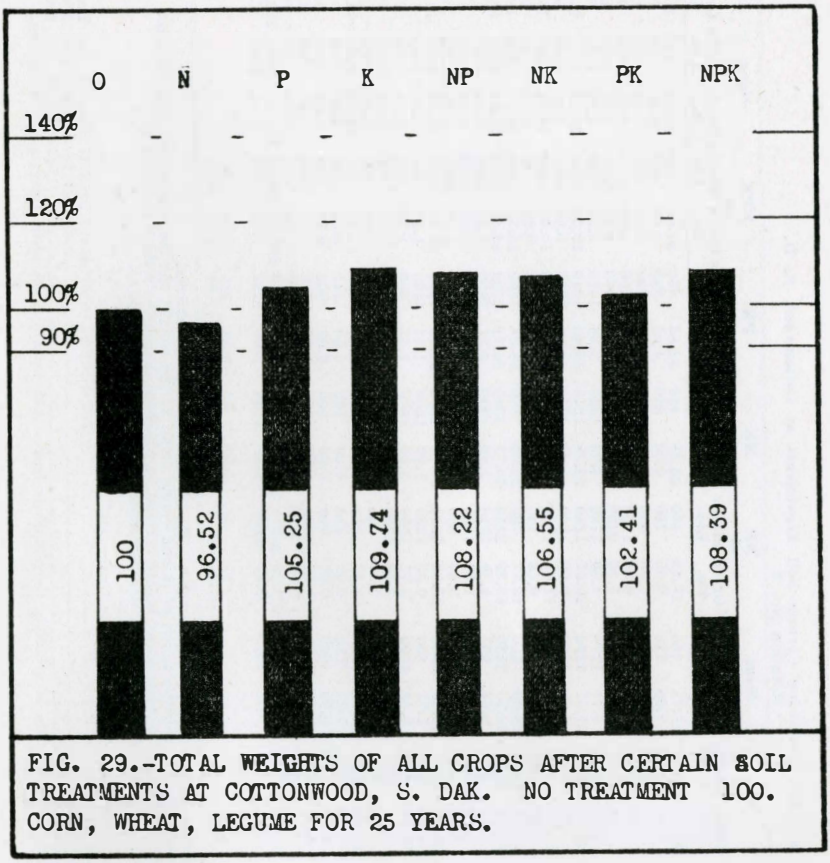

FIG. 29.-TOTAL WEIGHTS OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT COTTONWOOD, S. DAK. NO TREATMENT 100. CORN, WHEAT, LEGUME FOR 25 YEARS.

TABLE 22.—Yields of Corn Following Certain Soil Treatments at Cottonwood, S. D.
Rotation No. 3

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		–1		–2		–3		–4		–5		–6		–7		–8		–9		–10			
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	111-20	29.14	460	26.43	460	26.00	460	33.14	460	31.71	460	28.28	460	33.28	460	32.86	460	31.00	460	31.43	460	30.76	460
1913	311-20	0.00	450	0.00	400	0.00	430	0.00	420	0.00	710	0.00	760	0.00	850	0.00	890	0.00	840	0.00	810	0.00	657
1914	211-20	0.00	1000	0.00	1400	0.00	1250	0.00	1250	0.00	1050	0.00	950	0.00	1000	0.00	900	0.00	650	0.00	700	0.00	917
1915	111-20	0.00	2350	0.00	1800	0.00	2100	0.00	2300	0.00	2200	0.00	1700	0.00	3100	0.00	2100	0.00	2150	0.00	1200	0.00	1917
1916	311-20	11.14	2520	7.57	2670	3.71	2410	3.14	2400	6.29	2460	5.00	2250	3.00	1830	11.43	2880	6.57	2830	7.71	2160	8.33	2380
1917	211-20	7.29	1140	8.43	1265	6.57	1300	7.71	1340	6.71	1270	4.00	1180	4.93	1330	3.86	1420	3.57	1190	4.29	1070	6.10	1160
1918	111-20	19.14	1125	19.57	1145	17.14	910	22.71	1280	21.57	1260	20.57	1180	23.28	1245	19.43	1040	19.36	1030	20.14	1015	20.28	1133
1919	311-20	0.00	990	0.00	1390	0.00	1450	0.00	1840	0.00	1980	0.00	1640	0.00	1345	0.00	1295	0.00	1275	0.00	1400	0.00	1460
1920	211-20	15.28	1110	16.36	1255	14.57	1200	15.43	820	17.43	1900	11.43	1260	19.86	1630	14.57	1220	14.00	1040	16.14	1050	16.28	1353
* 1921	111-20	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.43	145	0.71	215	0.71	155	0.29	80	0.14	65	0.05	22
1922	311-20	19.43	700	20.86	900	17.14	800	21.43	1000	18.86	600	15.71	700	20.00	700	18.00	1300	15.71	600	15.71	900	18.00	733
1923	211-20	56.96	2110	61.25	2970	65.36	2840	63.75	3530	63.75	2530	63.39	2450	60.71	3500	60.71	2500	54.46	2150	57.68	2170	59.46	2270
1924	111-20	2.14	1150	1.86	570	0.71	650	0.71	550	0.64	955	1.29	1010	1.43	1000	0.71	1250	1.43	1300	2.43	1030	1.74	1045
1925	311-20	1.43	690	0.71	500	0.71	670	1.86	1070	3.14	1180	1.57	1530	1.57	940	2.14	970	3.00	1860	2.86	2100	2.48	1323
1926	211-20	7.50	860	4.36	560	5.82	560	4.00	800	4.18	940	3.64	660	4.11	760	7.07	1540	4.07	1460	5.86	1590	5.85	1130
1927	111-20	22.00	960	22.00	1560	19.57	2230	25.59	2310	24.86	2060	26.86	3220	30.14	1890	24.71	4270	28.00	3860	17.86	2950	21.57	1990
1928	311-20	2.57	1500	0.71	1200	0.14	1100	0.11	1100	1.71	800	0.50	1300	1.29	1400	1.14	1400	1.14	1300	1.50	1100	1.93	1133
1929	211-20	9.14	1000	10.86	1100	8.71	1400	10.14	1400	9.43	1100	2.71	1000	5.00	1000	1.57	900	1.14	700	4.29	800	7.62	967
1930	111-20	0.14	400	0.14	200	0.14	700	0.07	600	0.14	400	1.14	1300	2.43	700	0.07	200	0.43	700	1.71	900	0.66	567
1931	311-20	3.93	700	3.14	700	1.86	640	1.71	760	2.57	900	2.57	900	4.14	900	3.00	900	2.50	800	2.00	600	2.83	733
1932	211-20	12.14	1540	12.86	1730	17.14	1570	12.14	1680	14.29	1680	8.57	860	17.14	790	12.86	420	11.43	550	10.00	1000	12.14	1407
1933	111-20	0.00	20	0.00	100	0.00	40	0.00	20	0.00	180	0.00	180	0.00	100	0.00	240	0.00	160	0.00	200	0.00	133
1934	311-20	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000
1935	211-20	4.29	1800	6.29	2050	3.00	2650	4.00	2300	3.86	2200	1.57	2000	1.29	1700	1.57	1700	1.71	2100	1.86	1800	3.34	1933
1936	111-20	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000	0.00	000
TOTALS:		223.66	24575	223.40	25925	208.29	27360	228.27	29230	231.14	28815	199.23	28635	234.31	28385	216.41	29950	199.81	29085	203.61	27080	219.47	26823
25 Year Average		8.95	983	8.94	1037	8.33	1094	9.13	1169	9.25	1153	7.97	1145	9.37	1135	8.66	1198	7.99	1163	8.14	1083	8.78	1073
Increase over "Av. of None"				0.16	–36	–0.45	21	0.35	96			–0.81	72	0.59	62	–0.12	125	–0.79	90				
Increase per cent				1.82	–3.36	–5.13	1.96	3.99	8.95			–9.23	6.71	6.72	5.78	–1.37	11.65	–9.00	8.39				

NOTE.—The minus (–) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
In 1912 the fodder was removed after the corn was husked. Evidently much of it had blown away as the weight for the whole acre was 460 Lbs.
* In 1921 the corn was cut with a mower. On plots 111 to 115 it blew away before it could be weighted, hence the yield is recorded as 0.
The yields on the other plots were very light and does not increase the 25 year average materially over the other plots.

Summary For Corn Crops: Grain And Stalks

Average annual yield of grain, 25 years, from all plots ---------- 607 pounds, equivalent to 8.67 bushels per acre.
Average annual yield of stalks, 25 years, from all plots ---------- 1116 pounds per acre.
Average annual yield of grain and stalks, 25 years, from all plots ---------- 1723 pounds per acre.
Ratio of stalks to grain—pounds stalks: pounds grain—1.29. This is probably too small as leaves and tassels often blew away before weighing.

TABLE 23.—Yields of Wheat Following Certain Soil Treatments at Cottonwood, S. D.
Rotation No. 3

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	211-20	7.17	680	9.33	300	8.67	560	8.33	530	7.83	420	6.50	410	5.83	330	7.83	500	8.17	460	13.33	960	9.44	687
1913	111-20	0.00	700	1.42	350	1.00	350	0.67	360	0.75	365	0.00	1000	0.00	900	0.75	220	0.00	800	0.67	240	0.47	435
1914	311-20	2.33	520	2.67	460	3.33	500	4.00	540	4.83	630	3.33	510	5.00	550	4.83	580	4.67	790	4.83	710	4.00	620
1915	211-20	0.00	1420	0.00	1160	0.00	1540	0.00	1860	0.00	1760	0.00	1660	0.00	1220	0.00	1520	0.00	1210	0.00	1820	0.00	1667
1916	111-20	8.25	1245	5.00	1040	7.83	1970	10.00	1740	8.00	1480	7.58	2245	8.58	1685	9.50	1550	5.75	1575	7.83	1030	8.03	1252
1917	311-20	5.83	790	2.50	910	3.92	1010	6.83	1340	5.92	1650	2.17	1870	2.33	860	4.67	730	4.17	1040	6.25	840	6.00	1093
1918	211-20	4.58	805	6.00	1060	4.67	740	5.92	1125	6.33	900	1.75	875	1.83	810	1.50	750	1.33	960	2.75	435	4.55	713
1919	111-20	3.58	805	5.08	895	5.50	1240	5.67	900	3.58	905	5.67	1660	6.50	930	7.83	1630	3.92	1425	5.17	1030	4.11	913
1920	311-20	19.83	2730	24.17	3850	28.83	3330	30.83	3610	26.83	3290	22.50	4070	21.17	3830	25.83	3290	21.67	4100	24.17	2850	23.61	2957
1921	211-20	1.42	515	1.50	510	1.42	475	1.50	510	1.00	388	0.25	385	0.67	400	0.17	250	0.29	123	0.50	90	0.97	331
1922	111-20	12.00	2000	7.67	1410	16.50	2300	13.33	1430	11.83	1640	10.17	2870	11.00	1830	15.67	2790	12.17	2520	12.50	2300	12.11	1980
1923	311-20	14.50	2690	14.83	3400	19.00	3060	19.33	3340	17.83	3380	15.83	2800	18.17	2510	21.00	3040	18.50	2590	16.83	3590	16.39	3220
1924	211-20	8.67	1880	9.17	1150	11.33	1220	10.50	1070	10.50	1070	11.33	1320	10.00	1000	11.17	930	10.83	1250	7.67	840	8.95	1263
1925	111-20	3.33	300	3.67	480	3.83	570	4.50	730	4.67	220	5.33	1080	6.00	940	4.50	830	4.17	850	5.00	500	4.33	340
1926	311-20	5.83	1370	4.17	830	6.00	840	11.33	2580	14.00	2000	6.58	1725	7.17	3230	8.58	2045	7.92	2225	13.00	3500	10.94	2290
1927	211-20	27.67	2840	29.50	3170	27.17	3870	23.50	3390	25.83	2450	31.33	3620	31.83	3190	32.50	2950	27.50	3550	36.67	2100	30.06	2463
1928	111-20	10.83	850	10.58	965	11.83	690	12.25	1165	12.75	1135	16.83	1990	17.83	2030	13.75	1075	14.50	4030	10.50	1070	11.36	1018
1929	311-20	17.33	1960	16.67	2400	19.83	2410	23.00	2820	20.33	2980	13.17	3010	16.00	2940	22.50	2750	18.33	3500	22.00	2680	19.89	2540
1930	211-20	2.67	1120	3.00	1140	3.67	2360	5.17	1350	4.17	1210	1.00	980	1.67	840	0.83	850	0.33	820	1.33	780	2.72	1037
1931	111-20	0.17	390	0.69	460	0.12	353	0.42	415	0.33	340	1.67	700	3.67	980	0.67	420	1.50	730	3.00	800	1.17	510
1932	311-20	24.17	3450	22.67	3440	25.67	4160	27.33	4260	26.17	3730	20.33	3580	24.17	3450	30.17	3790	24.83	3810	26.33	3520	25.56	3567
1933		No wheat sown this year.																					
1934	111-20	0.50	20	0.33	90	1.58	205	1.67	300	2.00	80	2.67	400	3.42	495	2.67	340	1.50	290	2.00	460	1.50	187
1935	311-20	9.17	1650	7.17	1470	6.83	1790	7.33	1760	11.17	1830	8.67	1680	10.00	1900	11.17	1030	12.33	1960	14.33	2140	11.56	1873
1936	211-20	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
TOTALS		189.83	30730	187.79	30940	218.53	35543	233.41	37125	226.65	33853	194.66	40440	212.84	36850	238.09	33860	204.38	40608	236.66	34285	217.72	32956
24 Year Average		7.91	1280	7.82	1298	9.11	1481	9.73	1547	9.44	1411	8.11	1685	8.87	1535	9.92	1411	8.52	1692	9.86	1429	9.07	1373
Increase over "Av. of None"				−1.25	−84	0.04	108	0.66	174			−0.96	312	−0.20	162	0.85	38	−0.55	319				
Increase per cent				−13.78	−6.12	0.44	7.87	7.28	12.67			−10.58	22.72	−2.21	11.80	9.37	2.77	−6.06	23.23				

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
In 1915 rust and hail destroyed crop. In 1919, damaged by hail June 25 and 26. In 1920 lodging on plots 316 to 319.

Summary of Wheat Crops: Grain and Straw

Average annual yield of grain, 24 years, from all plots ---------- 536 pounds equivalent to 8.93 bushels per acre.
Average annual yield of straw, 24 years, fom all plots ---------- 1476 pounds per acre.
Average annual yield of grain and straw, 24 years, from all plots ---------- 2012 pounds per acre.
Ratio of straw to grain—pounds straw : pounds grain—2.75.

TABLE 24.—Yields of Legumes: Seed and Straw, Following Certain Soil Treatments at Cottonwood, S. D., Rotation No. 3

Crop	Year	Acre	None −1 Seed Bu.	None −1 Straw Lbs.	N −2 Seed Bu.	N −2 Straw Lbs.	P −3 Seed Bu.	P −3 Straw Lbs.	K −4 Seed Bu.	K −4 Straw Lbs.	None −5 Seed Bu.	None −5 Straw Lbs.	NP −6 Seed Bu.	NP −6 Straw Lbs.	NK −7 Seed Bu.	NK −7 Straw Lbs.	PK −8 Seed Bu.	PK −8 Straw Lbs.	NPK −9 Seed Bu.	NPK −9 Straw Lbs.	None −10 Seed Bu.	None −10 Straw Lbs.	Average of None Seed Bu.	Average of None Straw Lbs.
Peas	1912	311-20	4.00	2170	3.67	1720	4.00	920	5.67	2160	7.67	2340	3.33	860	4.00	2930	6.00	1440	5.33	1560	10.33	1920	7.33	2143
Peas	1913	211-20	Destroyed by drought. No crop.																					
Peas	1914	111-20	0.67	720	1.00	700	0.83	1100	1.17	1140	0.67	770	1.67	980	1.33	1300	0.83	1030	1.00	1270	1.17	1110	0.84	867
P&O	1915	311-20	Seeded to peas and oats. Cut for hay. No seed harvested.																					
S.Cl.	1916	211-20	Both cuttings for hay; no seed harvested.																					
S.Cl.	1917	111-20	One cutting only. Cut for hay. No seed.																					
S.Cl.	1918	311-20	Sweet clover failed. Drought. Seeded to peas and oats in spring of 1918. Cut for hay. No seed harvested.																					
S.Cl.	1919	211-20	One cutting only. Cut for hay. No seed crop.																					
S.Cl.	1920	111-20	One cutting only. Cut for hay. No seed crop.																					
S.Cl.	1921	311-20	One cutting only. Cut for hay. No seed crop.																					
S.Cl.	1922	211-20	2.50	2650	3.50	3990	5.17	4290	7.33	4360	7.33	4260	5.50	3970	4.67	3820	3.33	3000	3.67	3580	3.33	3000	4.39	3303
S.Cl.	1923	111-20	7.00	1980	5.33	2030	8.50	1690	9.83	2810	6.83	1190	6.67	2800	7.50	2600	10.17	2990	7.00	2130	8.50	1690	7.44	1620
S.Cl.	1924	311-20	0.33	1680	0.17	1090	0.17	2090	0.17	1490	0.25	1585	0.25	1585	0.58	1765	0.46	1570	0.54	2268	0.67	2460	0.42	1908
S.Cl.	1925	211-20	One cutting only. Cut for hay. No seed crop.																					
S.Cl.	1926	111-20	Sweet clover failed on account of drought. Seeded to soy beans which were destroyed by hail July 27, 1926.																					
S.Cl.	1927	311-20	Two cuttings. Both for hay. No seed. Very thin stand in spring. Reseeded to "Hubam," annual white sweet clover.																					
S.Cl.	1928	211-20	Two cuttings. Both cut for hay. No seed harvested.																					
S.Cl.	1929	111-20	Two cuttings. Both cut for hay. No seed harvested.																					
S.Cl.	1930	311-20	Failure due to drought. No growth.																					
S.Cl.	1931	211-20	Failure due to drought. No growth.																					
S.Cl.	1932	111-20	Sweet clover failed. Seeded to soy beans which also failed onaccount of drought.																					
S.Cl.	1933	311-20	Sweet clover failed. Winter-killed.																					
S.Cl.	1934	211-20	Failure. None of the plots made enough growth to mow although there was a good stand in the spring.																					
S.Cl.	1935	111-20	Failure. Seed failed to come up last year on account of dry weather.																					
S.Cl.	1936	311-20	Failure. No crop on account of drought.																					
TOTAL All Crops, 25 Yrs.			14.50	9200	13.67	9530	18.67	10090	24.17	11960	22.75	10145	17.42	10195	18.08	12415	20.79	10030	17.54	10808	24.00	10180	20.42	9841
Average All Crops			0.58	368	0.55	381	0.75	404	0.97	478	0.91	406	0.70	408	0.72	497	0.83	401	0.70	432	0.96	407	0.82	394
Increase over "Av. of None"					−0.27	−13	−0.07	10	0.15	84			−0.12	14	−0.10	103	0.01	7	−0.12	38				
Increase per cent					−32.93	−3.30	−8.54	2.54	18.29	21.32			−14.63	3.55	−12.20	26.14	1.22	1.78	−14.63	9.64				
TOTAL for Peas, 3 Yrs.			4.67	2890	4.67	2420	4.83	2020	6.84	3300	8.34	3110	5.00	1840	5.33	4230	6.83	2470	6.33	2830	11.50	3030	8.17	3010
Average, Peas, 3 Yrs.			1.56	963	1.56	807	1.61	673	2.28	1100	2.78	1037	1.67	613	1.78	1410	2.28	823	2.11	943	3.83	1010	2.72	1003
TOTAL S.Cl., 21 Yrs.			9.83	6310	9.00	7110	13.84	8070	17.33	8660	14.41	7035	12.42	8355	12.75	8185	13.96	7560	11.21	7978	12.50	7150	12.25	6831
Average S.Cl., 21 Yrs.			0.47	300	0.43	339	0.66	384	0.83	412	0.69	335	0.59	398	0.61	390	0.66	360	0.53	380	0.60	340	0.58	325
Average S. B'ns. 2 Yrs.			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0

PEAS: 3 Years Average yield per acre, all plots, ---------- Seed, 2.15 Bu. or 129 Lbs.; Straw, 938 Lbs.; Seed and Straw, 1067 pounds.
SWEET CLOVER: 21 Years, Average yield per acre, all plots ---------- Seed, 0.61 Bu. or 37 Lbs.; Straw, 364 Lbs.; Seed and Straw, 401 pounds.
SOY BEANS: 2 Years, Average yield per acre, all plots ---------- Seed, 0.00 Bu. or 0 Lbs.; Straw, 0 Lbs.; Seed and Straw, 0 pounds.
ALL CROPS: 25 Years, Average yield per acre, all plots ---------- Seed 0.77 Bu. or 46 Lbs.; Straw, 418 Lbs.; Seed and Straw, 464 pounds.
NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

TABLE 25.—Yields of Legume Hay Following Certain Soil Treatments at Cottonwood, S. D. Rotation No. 3

Treatment	None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.	−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Year Cut Acre	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total	Cut	Total
1912 1 311-20	Canada field peas cut for seed. See seed record.																					
1913 211-20	Canada field peas. Failure due to drought. No Yield.																					
1914 1 111-20	Canada field peas cut for seed. See seed record.																					
1915 *1 311-20	2000	2000	1850	1850	1850	1850	1500	1500	1200	1200	2150	2150	1850	1850	1600	1600	1850	1850	1450	1450	1550	1550
1916 1 211-20	3400		3400		4200		3600		3600		3700		3200		3000		3160		3400		3467	
1916 2 211-20	300	3700	600	4000	820	5020	620	4220	890	4490	900	4600	970	4170	740	3740	820	3980	800	4200	663	4130
1917 1 111-20	740	740	740	740	200	200	600	600	600	600	140	140	620	620	220	220	300	300	320	320	553	553
1918 †1 311-20	1060	1060	1260	1260	780	780	960	960	1000	1000	1240	1240	1380	1380	700	700	1660	1660	720	720	927	927
1919 1 211-20	2100	2100	2680	2680	2580	2580	2100	2100	2080	2080	2120	2120	2220	2220	1940	1940	2380	2380	1880	1880	2020	2020
1920 1 111-20	2090	2090	2180	2180	1580	1580	1460	1460	1670	1670	3110	3110	2175	2175	1675	1675	3330	3330	2650	2650	2137	2137
1921 1 311-20	1960	1960	1700	1700	2320	2320	2800	2800	2420	2420	1260	1260	1000	1000	1060	1060	1300	1300	1460	1460	1947	1947
1922 1 211-20	One cutting; for seed only. See seed record.																					
1923 1 111-20	One cutting; for seed only. See seed record.																					
1924 1 311-20	One cutting; for seed only. See seed record.																					
1925 1 211-20	2820	2820	2560	2560	4570	4570	3020	3020	2700	2700	2840	2840	2140	2140	2540	2540	2460	2460	2360	2360	2627	2627
1926 111-20	Sweet clover failed on account of drought. Seeded to soy beans which were destroyed by hail July 27, 1926.																					
1927 1 311-20	700		700		700		700		700		700		700		700		700		700		700	
1927 2 311-20	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000	300	1000
1928 1 211-20	2200		2000		3000		2100		1800		2100		1500		1100		1900		1500		1833	
1928 2 211-20	2000	4200	2000	4000	2000	5000	2400	4500	2100	3900	2400	4500	2400	3900	2500	3600	2700	4600	1900	3400	2000	3833
1929 1 111-20	1500		1400		1900		2000		2100		1100		500		2100		600		2800		2133	
1929 2 111-20	1900	3400	2300	3700	2000	3900	2300	4300	1800	3900	4300	5400	3400	3900	2400	4500	3300	3900	2200	5000	1967	4100
1930 311-20	Failure due to drought. No growth.																					
1931 211-20	Failure due to drought. No growth.																					
1932 111-20	Sweet clover failed. Seeded to soy beans which also failed on account of drought.																					
1933 311-20	Sweet clover failed. Winter-killed.																					
1934 211-20	None of the plots made enough growth to mow although there was a good stand in the spring. Drought.																					
1935 111-20	Sweet clover failed. Seeds did not germinate last year.																					
1936 311-20	Sweet clover failed. No sweet clover came up in the spring except in one low spot. Drought.																					
TOTALS. Yrs.																						
Peas 3	No hay. All cut for seed. See seed record.																					
Soy Beans 2	No hay or seed.																					
Peas & Oats 2	3060		3110		2630		2460		2200		3390		3230		2300		3510		2170		2477	
Sweet Clover 21	22010		22560		26170		24000		22760		24970		21125		20275		23250		22270		22347	
All Crops 25	25070		25670		28800		26460		24960		28360		24355		22575		26760		24440		24824	
AVERAGES: Yrs.																						
Peas and Oats 2	1530		1555		1315		1230		1100		1695		1615		1150		1755		1085		1239	
Sweet Clover 21	1048		1074		1246		1143		1084		1189		1006		965		1107		1060		1064	
All Crops 25	1003		1027		1152		1058		998		1134		974		903		1070		978		993	
Increase over "Av. of None"			34		159		65				141		−19		−90		77					
Increase per cent			3.42		16.01		6.55				14.20		−1.91		−9.06		7.75					

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

* 1915. Seeded to Canada field peas and oats to be cut for hay when the oats was in the milk.

† 1918. Seeded to Canada field peas and oats. Sweet clover failed.

SUMMARY

TABLE 26.—Summary of the Results From All Treatments on All Crops—Corn, Wheat, Legumes—in Rotation No. 3 at Cottonwood, S. D. Expressed as Weighted Averages

Crop	Corn-Grain		Corn-Stalks		Wheat-Grain		Wheat-Straw		Legume-Seed		Legume-Straw		Legume-Hay	
No. of Yrs.	25		25		24		24		25		25		25	
Treatment	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.
None	8.78		1073		9.07		1373		0.82		394		993	
N	8.94	0.16	1037	−36	7.82	−1.25	1289	−84	0.55	−0.27	381	−13	1027	34
P	8.33	−0.45	1094	21	9.11	0.04	1481	108	0.75	−0.07	404	10	1152	**159**
K	9.13	**0.35**	1169	96	9.73	0.66	1547	174	0.97	**0.15**	478	84	1058	65
NP	7.97	−0.81	1145	72	8.11	−0.96	1685	312	0.70	−0.12	408	14	1134	141
NK	9.37	0.59	1135	62	8.87	−0.20	1535	162	0.72	−0.10	497	**103**	974	−19
PK	8.66	−0.12	1198	**125**	9.92	**0.85**	1411	38	0.83	0.01	401	7	903	−90
NPK	7.99	−0.79	1163	90	8.52	−0.55	1692	**319**	0.70	−0.12	432	38	1070	77

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
N	1.82	−3.36	−13.78	−6.12	−32.93	3.30	3.42
P	−5.13	1.96	0.44	7.87	−8.54	2.54	**16.01**
K	3.99	8.95	7.28	12.67	18.**29**	21.32	6.55
NP	−9.23	6.71	−10.58	22.72	−14.63	3.55	14.20
NK	**6.72**	5.78	−2.22	11.80	−12.20	**26.14**	−1.91
PK	−1.37	**11.65**	**9.37**	2.77	1.22	1.78	−9.06
NPK	−9.00	8.39	−6.06	**23.23**	−14.63	9.64	7.75

None—no treatment. N—nitrogen. P—phosphorus. K—potassiuin.
NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment.
The figures indicating the greatest increase in yield in each crop are printed in bold face type.

GENERAL SUMMARY

TABLE 27.—General Summary of the Results From All Treatments on All Crops: Corn, Wheat, Legumes in Rotation No. 3 Expressed in Terms of the Total Amounts of Dry Matter Produced Per Acre for Twenty-Five Years. Cottonwood, S. D.

Treatment / Crop	No. Acre Yrs.	None Grain Lbs.	N Grain Lbs.	P Grain Lbs.	K Grain Lbs.	NP Grain Lbs.	NK Grain Lbs.	PK Grain Lbs.	NPK Grain Lbs.
Corn	25	15,375	15,650	14,575	15,975	13,950	16,400	15,150	13,975
Wheat	24	13,056	11,256	13,128	14,016	11,688	12,768	14,280	12,264
Legume Seed	25	1,225	825	1,125	1,450	1,050	1,075	1,250	1,050
Total	(74)	29,656	27,731	28,828	31,441	26,688	30,243	30,680	27,289
Total Gain		------	−1,925	−828	1,785	−2,968	587	1,024	−2,367
Av. Gain per Yr.		------	−26.0	−11.2	24.1	−40.1	7.9	13.8	−32.0
Gain per cent		------	−6.48	−2.79	6.01	−10.00	1.97	3.44	−7.98

		Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay
Corn	25	26,825	25,925	27,350	29,225	28,625	28,375	29,950	29,075
Wheat	24	32,952	30,936	35,544	37,128	40,440	36,840	33,864	40,608
Legume Straw	25	9,850	9,525	10,100	11,950	10,200	12,425	10,025	10,800
Legume Hay	25	24,825	25,675	28,800	26,450	28,350	24,350	22,575	26,750
Total	(74)	94,452	92,061	101,794	104,753	107,615	101,990	96,414	107,233
Total Gain		------	−2,391	7,342	10,301	13,163	7,538	1,962	12,781
Av. Gain per Yr.		------	−32.3	99.2	139.2	177.9	101.9	26.5	172.7
Gain per cent		------	−2.53	7.77	10.91	13.94	7.99	2.08	13.53

Total Amount of Dry Matter Produced Under the Several Treatments

	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay
Corn	42,200	41,575	41,925	45,200	42,575	44,775	45,100	43,050
Wheat	46,008	42,192	48,672	51,144	52,128	49,608	48,144	52,872
Legumes	35,900	36,025	40,025	39,850	39,600	37,850	33,850	38,600
Total	124,108	119,792	130,622	136,194	134,303	132,233	127,094	134,522
Total Gain	------	−4,316	6,514	12,086	10,195	8,125	2,986	10,414
Av. Gain per Yr.	------	−58.3	88.0	163.3	137.8	109.8	40.4	140.7
Gain per cent	------	−3.48	5.25	9.74	8.22	6.55	2.41	8.39

General Summary of the Increases in Yield for the Several Treatments Over No Treatment for All Crops Grown

Total Gain Grain 25 Years	−1,925	−828	1,785	−2,968	587	1,024	−2,367
Total Gain Straw, etc., 25 Years	−2,391	7,342	7,301	13,163	7,538	1,962	12,781
Total Gain Dry Matter	−4,316	6,514	12,086	10,195	8,125	2,986	10,414
Gain per cent Grain 25 Years	−6.48	−2.79	6.01	10.00	1.97	3.44	−7.98
Gain per cent Straw, etc., 25 Years	−2.53	7.77	10.91	13.94	7.99	2.08	13.53
Gain per cent Total Dry Matter	−3.48	5.25	9.74	8.22	6.55	2.41	8.39

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
NOTE.—The minus (−) sign indicates decrease.
The average yields per acre per year for None (No Treatment) for all crops were: Grain, 401 lbs.; Straw, etc., 1276 lbs.; total, 1677 lbs.

Part III
Soil Fertility Investigations at Eureka, S. D.
Complete Fertility Test

Introduction.—The results here reported from the complete fertility test have been obtained from a project carried on at the Eureka Experiment Substation. The project has been supported by funds appropriated biennially by the South Dakota legislature.

History.—The project was begun in 1912 and was in progress until 1936, a period of 25 years, when it was suspended because of lack of funds to pursue it further.

Object.—Before the project was begun nothing was known of the plant food requirement of the soils of that part of the state (see map on page 3). It was thought that long-continued field trials with the application of plant food elements would result in information that would form the basis for soil management practices which would maintain the plant food supply in the soil and perhaps result permanently in more profitable crop yields.

Plan of the Work.—The project was located on three "blocks" of land on the Eureka Experiment Station each of which was divided into 10 plots two rods wide and eight rods long, containing one-tenth of an acre. The plots are separated by alleys four feet in width which have been kept clear of weeds by frequent cultivation. The blocks of 10 plots each are separated by roads 20 feet in width.

The general plan of the plots, as well as their numbers and fertility treatments applied, is shown in Figure 32.

The original plan of the project has been carried out with the exception of the substitution of certain crops for the regular crops which is indicated in the tables of crop yields. It was also necessary to suspend potassium applications during the Great War.

Soil.—The soil on which the fertility plots are located is classified in the unpublished report of the Reconnaissance Survey of the Soils of South Dakota as Williams loam. This soil type covers an extended area east of the Missouri River and is bounded on the east by the extensive area of soils belonging to the Barnes series of soils which it resembles in many respects.

Like the Barnes soils it is weathered from material deposited by the glacier which once covered nearly all of South Dakota east of the Missouri River.

The surface soil of Williams loam to a depth varying from 7 to 12 inches, consists of loose friable very dark grayish brown loam of finely granular structure. The subsurface layer is of a lighter grayish brown and is underlain by friable material of grayish or grayish yellow color. This layer contains a large amount of calcium carbonate, or "lime," which has been leached downward by the percolating rain water.

The Williams soils have been weathered from glacial drift under a rainfall less than that under which the Barnes soils have been formed.

Crop Rotation.—The crop rotation is the same as that employed in the complete fertility tests at Cottonwood, namely, corn followed by wheat followed by a legume crop, usually white sweet clover.

0	101
N	102
P	103
K	104
0	105
NP	106
NK	107
PK	108
NPK	109
0	110

0	201
N	202
P	203
K	204
0	205
NP	206
NK	207
PK	208
NPK	209
0	210

0	301
N	302
P	303
K	304
0	305
NP	306
NK	307
PK	308
NPK	309
0	310

ROTATION NO. 1.

CORN-WHEAT-LEGUME: SOIL FERTILITY TEST.

EXPERIMENT SUBSTATION, EUREKA, S. D.

Fig. 32.—Plan of the Complete Fertility Plots at the Experiment Substation at Eureka

The letters indicate the kind of fertilizer applied to the several plots:

O means nothing applied; often referred to as "No Treatment" or "None."

N means nitrogen applied in nitrate of soda at the rate of 350 pounds per acre.

P means phosphorus applied in acid phosphate at the rate of 200 pounds per acre.

K means potassium applied in potassium chloride at the rate of 200 pounds per acre.

Each letter has a uniform meaning whether it occurs alone or in combination with other letters.

The varieties of crops grown have been as follows:

Corn—1912, Minnesota 13; 1913 and 1914, S.D. 86; 1915, Eureka 86; 1916, Eureka 71; 1917 to 1936, Northwestern Dent 971.

Wheat—1912, 1913, Red Fife S.D. 67; 1914 to 1917, Kubanka 75; 1918 to 1934, Acme 284; 1935, 1936, Mindum. All of the varieties except Red Fife are durum wheats.

Legume—Biennial white sweet clover, S.D. 190.

Soil Preparation.—The soil is fall plowed to a depth of seven inches before the corn crop. The soil is usually dry and breaks into clods when plowed but the effect of the weather is to break these clods into smaller granules before spring when the disk and harrow are used to form a suitable seed bed.

The corn stubble is allowed to stand over winter and is then prepared for seeding wheat the spring of the second year by using a disk and harrow.

Sweet clover has been seeded for 22 years and is sown in the spring with the wheat.

Peas were grown from 1912-1914 and the land plowed in preparation of the seed bed. Soy beans were seeded when sweet clover failed in 1920 and 1932.

Plant Food Applications.—No organic matter has been returned to the soil except the crop stubbles.

Phosphorus is applied in the form of acid phosphate at the rate of 200 pounds per acre. Potassium is applied in the form of potassium chloride at the rate of 200 pounds per acre. Nitrogen is applied in the form of nitrate of soda at the rate of 300 pounds per acre.

Applications of nitrogen, phosphorus, and potassium are made broadcast on the soil in the spring before disking preceding the corn crop and wheat crop. No applications are made the year the legume is grown.

Reference to Figure 32 shows that each element of plant food is applied alone and in all combinations with the other two.

Harvesting Crops.—All plots are harvested and threshed separately and the yields of seed, grain, straw, and hay carefully weighed and permanently recorded.

Yields.—In the following tables the yields of the several crops for each year grown and the average yields for each crop and for all crops for the entire period of 25 years are recorded. A careful study of these data will reveal many facts not included in the necessarily brief discussion.

Corn—Table No. 28 is a record of all corn yields and shows that for the 24-year period for which there are records the average yields of corn per acre following the several soil treatments are as follows:

	Average Yield per Acre	Increase over no treatment	Increase per cent
	bu.	bu.	
No treatment	20.30		
Nitrogen	19.01	–1.19	–5.87
Phosphorus	18.38	–1.82	–9.01
Potassium	19.22	–0.98	–4.85
Nitrogen and phosphorus	20.21	0.01	0.05
Nitrogen and potassium	19.54	–0.66	–3.27
Phosphorus and potassium	19.81	–0.39	–1.93
Nitrogen, phosphorus and potassium	19.65	–0.55	–2.72

The minus sign (–) indicates decrease.

The variation in yields following the several soil treatments is small and it appears that the application of plant food has decreased the yield in all cases except where nitrogen and phosphorus are applied, and even in this instance the increase is insignificant.

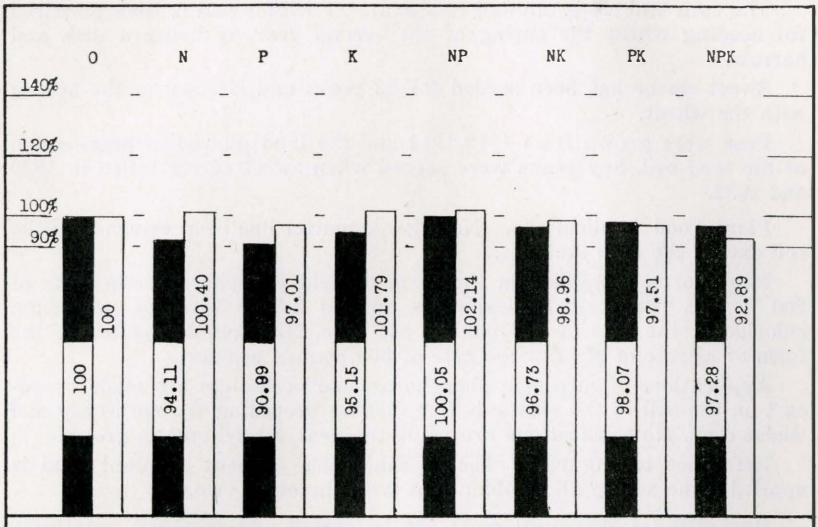

FIG. 33.—CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT EUREKA, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

Average yields of corn stalks following the several soil treatments are also shown in Table 28 and comparative yields of both corn and stalks are shown in Figure 33.

Wheat—Table No. 29 is a record of all wheat yields and shows that for the 24-year period for which complete records exist the average yields of wheat following the several soil treatments are as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	12.48		
Nitrogen	11.01	–1.46	–11.70
Phosphorus	11.22	–1.26	–10.10
Potassium	12.66	0.18	1.44
Nitrogen and phosphorus	11.50	–0.98	–7.85
Nitrogen and potassium	12.08	–0.40	–3.21
Phosphorus and potassium	13.83	1.35	10.82
Nitrogen, phosphorus and potassium	12.73	0.25	2.00

The minus sign (–) indicates decrease.

The treatment followed by the greatest increase in yield over no treatment is phosphorus and potassium, 10.82 per cent. Phosphorus alone was followed by a decrease of 10.10 per cent and nitrogen a decrease of 11.70 per cent. The yields of wheat straw are also recorded in Table 29. The comparative yields of both grain and straw are shown in Figure 34.

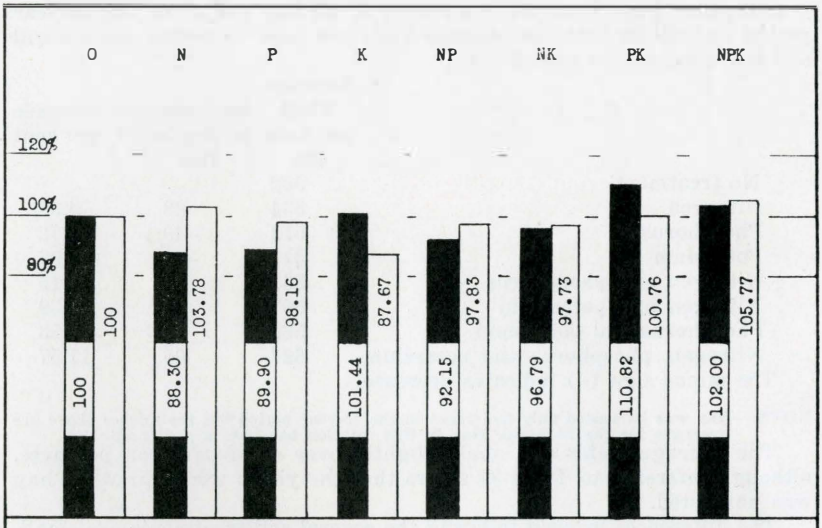

FIG. 34.-WHEAT YIELDS AFTER CERTAIN SOIL TREATMENTS AT EUREKA, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED.

Legumes—1. Seed Crop. Table No. 30 is a record of all the yields of legume seed and shows that for the 25-year period the average yield per acre of all crops following the several soil treatments were as follows:

	Average Yield per Acre	Increase over no treatment	Increase per cent
	bu.	bu.	
No treatment	2.63		
Nitrogen	2.75	0.12	4.56
Phosphorus	1.93	–0.70	–26.62
Potassium	2.21	–0.40	–15.59
Nitrogen and phosphorus	2.11	–0.52	–19.77
Nitrogen and potassium	1.93	–0.70	–26.62
Phosphorus and potassium	1.70	–0.93	–35.36
Nitrogen, phosphorus and potassium	2.12	–0.51	–19.39

The minus sign (–) indicates decrease.

The outstanding fact is that while the actual yields are small the soil treatments, except nitrogen alone, were followed by marked percentage decreases. Nitrogen alone produced an increase and this is too small to be significant.

Table 30 also shows the yields of legume straw following the several soil treatments. Figure 35 shows graphically the several yields of both seed and straw.

2. Legume Hay. Table 31 is a record of all hay yields for the 25-year period and shows that the average yield per acre following the several soil treatments were as follows:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	562		
Nitrogen	534	–28	–4.98
Phosphorus	513	–49	–8.72
Potassium	511	–51	–9.07
Nitrogen and phosphorus	561	–1	–0.15
Nitrogen and potassium	567	5	0.89
Phosphorus and potassium	565	3	0.53
Nitrogen, phosphorus and potassium	627	65	11.57

The minus sign (–) indicates decrease.

NOTE.—Hay was harvested only five years in the 25-year period but the figures above are averages for the 25 years. Hay in this rotation has been a poor crop.

The average yields are small, slightly over one-fourth ton per acre, although reference to Table 31 shows that the yields were fair when hay was harvested.

The differences in yield followng the several soil treatments are small. The largest increase, 11.57 per cent, followed nitrogen, phosphorus and potassium. Each of the three elements when applied alone produced decreased yields.

Figure 35 shows graphically the yields of hay following the several soil treatments.

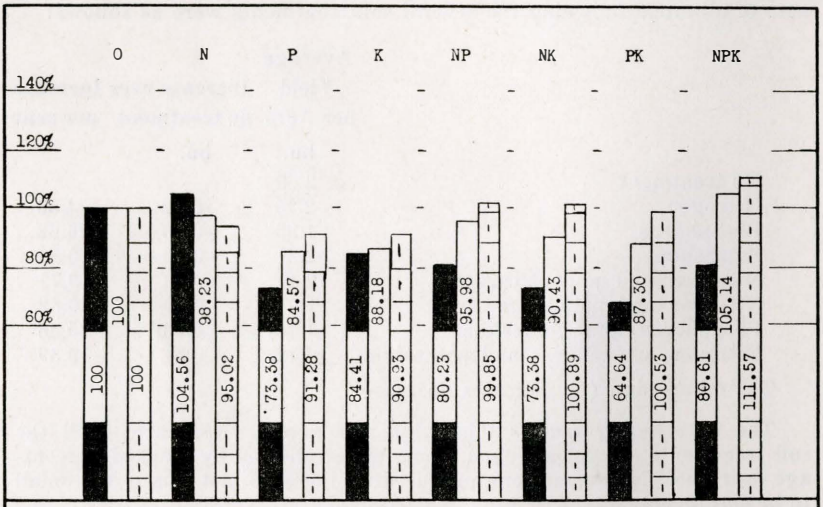

FIG. 35.–LEGUME YIELDS AFTER CERTAIN SOIL TREATMENTS AT EUREKA, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED; HAY BARRED.

Summary.—Table No. 32 is a record of the average yield per acre for each crop for the 25-year period following the several soil treatments as well as the gain or loss in yield as compared with the yields from plots receiving no treatment.

Table No. 33 records the total average yield for all crops following the several soil treatments, the average increase or decrease in yield, and the average increase or decrease per cent of yields as compared with the average total yield from the plots receiving no treatment.

The yields of all dry matter harvested following the several soil treatments are shown graphically in Figure 36 and Figure 37.

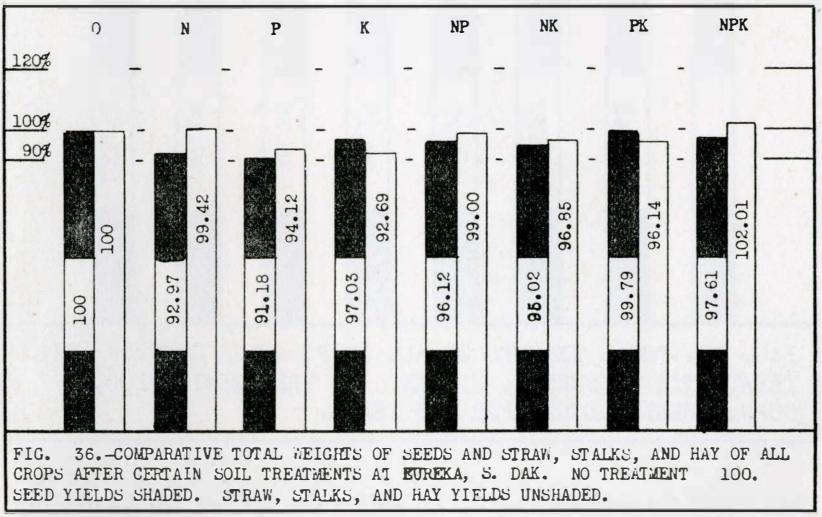

FIG. 36.—COMPARATIVE TOTAL WEIGHTS OF SEEDS AND STRAW, STALKS, AND HAY OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT EUREKA, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW, STALKS, AND HAY YIELDS UNSHADED.

From the data recorded in these tables and figures the following brief summary may be made:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	2,740		
Nitrogen	2,698	–42	–1.55
Phosphorus	2,556	–184	–6.70
Potassium	2,568	–172	–6.28
Nitrogen and phosphorus	2,690	–50	–1.81
Nitrogen and potassium	2,640	–100	–3.66
Phosphorus and potassium	2,662	–78	–2.84
Nitrogen, phosphorus and potassium	2,761	21	0.78
Average yield for all treatments	2,664		

The minus sign (–) indicates decrease.

The outstanding fact shown in this summary is that all of the soil treatments except nitrogen, phosphorus and potassium were followed by yields slightly less than those after no treatment. Another important

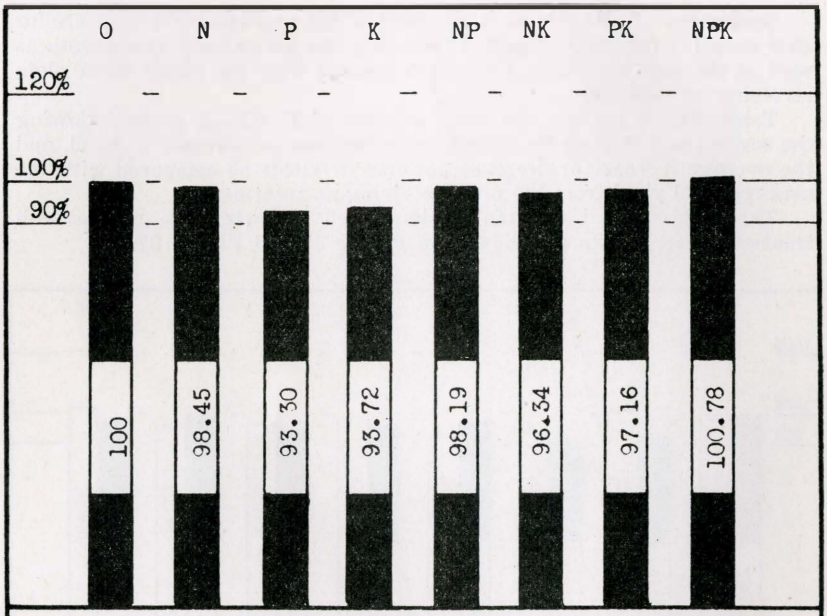

FIG. 37.-TOTAL WEIGHTS OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT EUREKA, S. DAK. NO TREATMENT 100. CORN, WHEAT, LEGUME FOR 25 YEARS.

fact is that the average yield of dry matter per acre in this rotation for 25 years has been about 1 ⅓ tons.

Precipitation.—Plate III is a record of the monthly and annual precipitation at Eureka, from 1909 to 1937, a period of 29 years.

Figure 38 shows graphically the annual precipitation at Eureka, for the same period. The average annual rainfall, including melted snow, has been 15.844 inches and the total amount 38 feet, 3.47 inches. Figure 39 shows graphically the average monthly precipitation for the same time.

A study of these data in connection with the crop yields will reveal many interesting facts which need not be repeated in this discussion.

One inch of rainfall over one acre weighs 226,350 pounds. Knowing the weight of dry matter produced per acre under a certain number of inches of rainfall it is possible to compute the efficiency of the rainfall in producing a pound of dry matter.

During the period of the project, 1912 to 1936, the average annual precipitation has been 16.013 inches and the total weight of the average rainfall has been 3,624,543 pounds per acre.

PRECIPITATION RECORD, EUREKA, S.D.

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.	ANNUAL
1909	0.30	0.45	0.14	0.50	2.65	3.35	2.16	1.39	1.25	0.17	0.45	2.40	15.21
1910	.60	1.70	1.23	.82	.42	3.80	.53	2.60	3.65	.18	T	.25	15.78
1911	.41	.73	.62	2.24	.97	1.29	.45	3.57	1.15	.61	.88	.80	13.72
1912	.25	.40	1.05	1.29	3.37	1.50	2.19	3.27	1.43	.07	T	.11	14.93
1913	.10	.03	.09	.68	1.97	2.91	2.16	1.53	.54	1.52	.08	.52	12.13
1914	.22	.05	.22	2.07	2.20	4.28	1.25	2.11	.70	.87	T	.53	14.50
1915	.90	1.08	.23	1.83	2.58	4.66	3.38	2.47	3.74	3.10	.56	.36	24.89
1916	.79	.13	1.78	.88	3.59	4.16	3.70	4.62	1.05	.29	.23	.06	21.28
1917	.60	.20	1.46	2.18	1.30	1.61	1.04	.93	.67	.26	.20	.75	11.20
1918	.50	.60	.58	1.98	1.97	.93	1.03	1.77	.36	.55	.53	.20	11.00
1919	.07	1.04	.52	1.28	3.68	2.29	4.08	.77	.04	1.63	.22	.12	15.70
1920	.16	.08	.27	1.63	1.74	4.26	2.71	2.05	3.90	.36	.54	.09	17.79
1921	.44	.23	1.27	3.74	3.31	.52	4.51	4.45	3.29	1.64	.36	.24	24.00
1922	.16	.94	.30	.89	3.39	3.38	1.66	.45	.54	.63	3.90	.23	16.47
1923	.13	.17	.35	1.31	3.56	4.17	3.67	1.79	2.56	1.52	.22	.20	19.65
1924	.02	.24	.48	1.28	.44	5.24	3.29	1.35	2.65	2.16	T	.27	17.42
1925	.41	.01	.17	2.41	1.08	6.56	.70	1.48	1.38	.36	.57	.54	15.67
1926	.30	.20	.05	.75	2.65	1.18	1.16	2.45	3.93	.84	.16	.45	14.12
1927	.40	.45	.24	1.31	3.72	2.90	6.39	3.43	1.28	1.89	.14	.39	22.54
1928	.36	.07	.12	1.31	.11	4.57	3.68	2.56	3.30	1.15	.52	.11	17.86
1929	.61	.24	.36	1.16	1.57	.77	2.42	.70	1.55	2.57	.17	.10	12.22
1930	.11	1.08	T	1.43	2.66	1.00	1.06	3.94	.74	1.97	.63	.18	14.80
1931	.10	.38	.86	.81	2.54	5.17	1.30	5.34	.98	1.43	.62	.59	20.12
1932	.18	.02	.31	1.89	5.18	5.19	1.95	1.18	1.28	1.08	.02	.08	18.36
1933	.24	.10	.74	1.23	3.03	3.28	3.27	1.28	.60	.05	.26	.15	14.23
1934	T	.01	.49	.03	.25	2.61	.72	.39	.90	1.64	.15	.14	7.33
1935	.13	.32	1.29	3.25	2.52	3.47	3.38	1.09	.24	.04	.26	.17	16.16
1936	.20	.10	.69	.69	.74	1.16	.18	.98	.15	.24	.58	.14	5.85
1937	.39	.12	.41	.58	2.08	2.66	3.78	3.04	.82	.12	.15	.39	14.54
AV.	.31	.39	.56	1.43	2.25	3.06	2.34	2.17	1.54	1.00	.43	.36	15.844

T indicates trace of precipitation, less than .01 inch.

Plate III.—The Monthly and Annual Precipitation at Eureka, S. D.

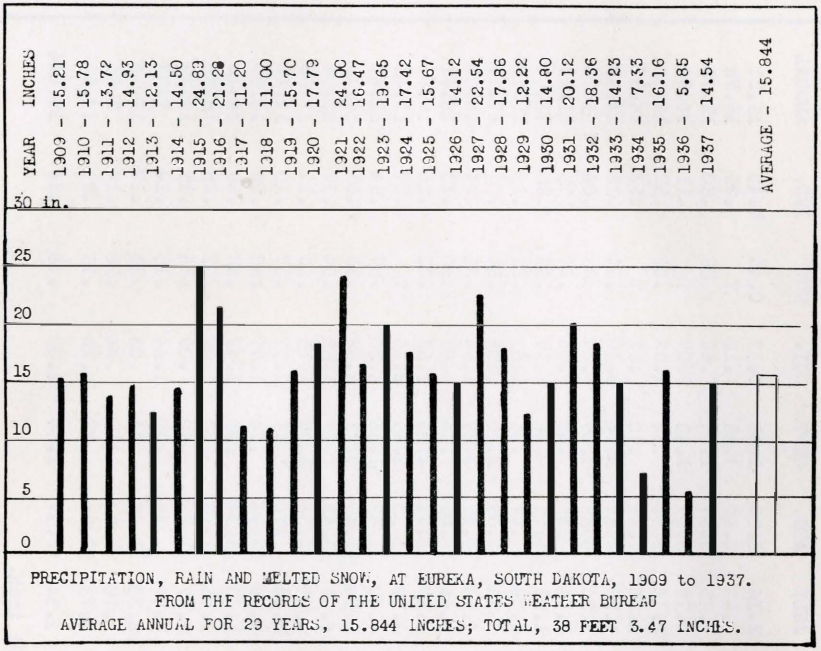

Fig. 38.—The Annual Precipitation at Eureka, S. D.

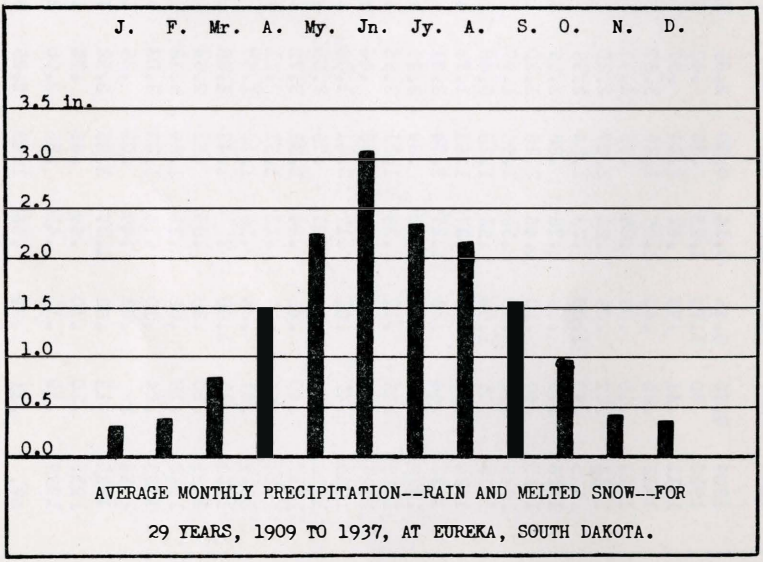

Fig. 39.—The Average Precipitation by Months at Eureka, S. D.

The number of pounds of water required to produce one pound of dry matter in the several crops grown on the plots receiving no soil treatment is as follows:

Kind of Crop Grown Including Grain, Straw, Stalks and Hay	Average Yield Total Dry Matter per acre per year	Pounds of Water to Produce 1 lb. of Dry Matter
Corn	3,424 lbs.	1,059 lbs.
Wheat	2,865	1,265
Legume	1,964	1,845
Average all crops	2,740	1,323

Conclusions.—With all the facts in mind the only conclusion which can be drawn is that under the conditions of this project the supply of plant food in the soil does not limit the crop yields. In the future plant food may be a factor but it has not been significant in the 25-year period on the soil under investigation.

Corn produced the most dry matter per unit of water and legume crops the least. The amount of water required to produce a unit of dry matter on this project when considered with the amount of rainfall which may be expected at Eureka over a period of years may serve as a basis upon which farming systems may be based.

TABLE 28.—Yields of Corn Following Certain Soil Treatments at Eureka, S. D.
Rotaion No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		-1		-2		-3		-4		-5		-6		-7		-8		-9		-10			
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	101-10	40.43	1250	53.85	1400	53.57	1150	42.86	1450	54.28	1350	54.28	1150	53.57	1750	62.57	1250	62.43	1050	69.57	1300	54.76	1300
1913	301-10	11.57	1270	11.43	1170	10.14	1480	11.14	1400	13.14	1260	12.14	1440	10.29	1200	9.29	960	12.29	1070	13.86	1180	12.86	1237
1914	201-10	17.71	1750	17.00	1800	15.28	1750	15.00	1700	20.00	1600	17.86	1550	16.28	1550	14.14	1550	15.43	1650	18.86	1500	18.86	1617
1915	101-10	0.00	5500	0.00	7000	0.00	5850	0.00	5800	0.00	5650	0.00	7150	0.00	7100	0.00	7250	0.00	7500	0.00	6250	0.00	5800
1916	301-10	21.71	2480	18.14	2230	23.86	2830	30.00	3150	37.71	3810	33.86	3880	31.57	3790	31.28	3410	21.86	2720	18.57	2200	26.00	2830
1917	201-10	5.00	2000	4.86	2000	5.57	2000	6.29	2000	7.86	2000	6.43	2000	5.57	1600	6.43	1600	5.86	2000	9.57	2000	7.48	2000
1918	101-10	4.86	1800	3.57	1850	1.57	1850	1.71	1500	3.28	1700	2.57	1650	3.71	1250	2.29	1550	3.00	1700	4.43	1500	4.19	1667
1919	301-10	27.71	2530	23.57	2070	21.28	2490	24.86	2000	25.71	1890	22.00	1850	26.71	1850	29.57	1970	32.00	2080	29.28	2020	27.57	2147
1920	201-10	41.86	3900	42.43	2100	38.00	3700	42.14	2150	41.71	3650	37.43	3050	24.43	2650	25.00	1750	32.00	1700	37.43	1750	40.33	3100
1921	101-10	33.14	2800	48.71	3000	46.71	2000	47.57	3000	38.14	2000	50.43	2000	50.43	2000	54.14	2750	54.00	2250	54.00	2000	41.76	2267
1922	301-10	32.43	3500	32.57	4250	31.71	3150	29.86	3850	30.00	4030	30.14	3390	29.28	2820	31.71	3200	33.43	4170	50.00	4700	37.48	4077
1923	201-10	49.00	2200	47.43	2150	46.57	2000	50.14	2150	49.85	2000	50.14	2250	47.14	2100	47.85	2500	48.00	2200	51.57	2300	50.14	2167
1924	101-10	21.00	1800	24.00	2000	17.57	1950	20.57	2150	24.00	2000	27.57	2250	26.28	2100	27.71	2400	27.28	2100	22.50	1950	22.50	1917
1925	301-10	25.00	1250	25.00	1250	27.14	1300	25.71	1200	25.00	1050	21.43	1350	21.43	1300	20.71	1250	22.86	1400	25.00	1350	25.00	1217
1926	201-10	0.00	250	0.00	250	0.07	245	0.00	250	0.07	195	0.00	150	0.07	145	0.07	145	0.07	95	0.14	90	0.07	178
1927	101-10	29.71	4420	19.28	2150	22.86	2300	33.43	3410	39.71	4170	42.57	3870	42.43	4280	44.28	4150	42.43	2380	40.14	2190	36.52	3593
1928	301-10	13.57	--	14.43	--	14.43	--	14.71	--	18.00	--	18.00	--	17.86	--	13.86	--	9.43	--	6.14	--	12.57	--
1929	201-10	9.71	2090	7.00	1550	5.14	1480	6.14	1840	8.00	1070	7.71	1220	8.00	1140	7.00	1110	9.00	1040	16.00	1300	11.24	1487
1930	101-10	8.86	2380	5.00	1800	2.43	1480	4.29	1950	6.71	1830	6.14	1570	5.71	1600	5.57	1260	5.71	1250	7.14	1300	7.57	1837
1931	301-10	17.00	2360	16.00	1880	18.71	1940	14.57	1780	14.14	1660	12.14	1750	12.86	1850	12.14	1750	6.43	1300	6.43	1050	12.52	1690
1932	201-10	27.71	2260	28.57	2250	26.43	1900	28.57	2200	25.71	1800	21.57	1740	28.57	1750	20.00	1500	18.14	1330	16.28	1610	23.23	1890
1933	101-10	Cut for fodder. No record of weights. Plants too thick. Cut when plants began to show effects of drought.																					
1934	301-10	Failure. Drought. No record of any yields.																					
1935	201-10	11.71	2680	13.43	2260	12.14	2000	11.71	2130	12.14	2100	10.71	1950	11.71	1930	9.71	1770	9.86	1960	12.71	1860	12.19	2213
1936	101-10	Failure. Drought. No record of any yields.																					
TOTALS: Years																							
Grain 24; Stalks 23		449.69	50470	456.27	46410	441.18	44845	461.27	47060	495.17	46815	485.12	47210	468.90	45755	475.32	45075	471.51	42945	509.62	41400	484.84	46231
Averages: Years																							
Grain 24; Stalks 23		18.74	2194	19.01	2018	18.38	1950	19.22	2046	20.63	2035	20.21	2053	19.54	1989	19.81	1960	19.65	1867	21.23	1800	20.20	2010
Increase over																							
"Av of None"				-1.19	8	-1.82	-60	-0.98	36			0.01	43	-0.66	-21	-0.39	-50	-0.55	-143				
Increase per cent				-5.89	0.40	-9.01	-2.99	-4.85	1.79			0.05	2.14	-3.27	-1.04	-1.93	-2.49	-2.72	-7.11				

NOTE.—The minus sign (-) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

Summary: Grain, 24 Years; Stalks, 23 Years

Average yield from all plots ---------- Grain, 1375 pounds; Stalks, 1991 pounds; Total, 3366 pounds. Grain 19.64 Bu. per acre.
Average yields from all plots, No Treatment ---------- Grain, 1414 pounds; Stalks, 2010 pounds; Total, 3424 pounds. Grain 20.20 Bu. per acre.
Average yield from all plots receiving Nitrogen "N" ---------- Grain, 1372 pounds; Stalks, 1982 pounds; Total, 3254 pounds. Grain 19.60 Bu. per acre.
Average yield from all plots receiving Phosphorus "P" ---------- Grain, 1366 pounds; Stalks, 1958 pounds; Total, 3324 pounds. Grain 19.51 Bu. per acre.
Average yield from all plots receiving Potassium "K" ---------- Grain, 1369 pounds; Stalks, 1966 pounds; Total, 3335 pounds. Grain 19.56 Bu. per acre.

NOTE.—1915—"Did not ripen; not husked. Cut for fodder and sold for $9.00 per ton."
1928—"Corn husked in field and stalks left standing. Too short to cut with binder." No yield of stalks recorded.

WHEAT

TABLE 29.—Yields of Wheat Following Certain Soil Treatments at Eureka, S. D.
Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	201-10	1.33	1020	0.83	1050	5.83	965	0.33	1030	1.00	1140	0.50	970	0.17	990	1.08	1185	2.17	2270	2.67	1590	1.67	1250
1913	101-10	4.75	815	8.00	1220	5.67	885	4.92	780	9.08	1130	8.42	1220	7.25	1090	11.25	1350	14.25	1745	16.00	1795	9.84	1247
1914	301-10	9.67	2420	10.03	2530	10.03	2580	10.83	2450	11.33	2520	11.50	2760	11.33	2720	10.50	2770	11.17	3180	12.50	2950	11.17	2630
1915	201-10	46.50	5010	42.66	4740	40.83	4700	43.50	4590	45.16	4840	42.00	4830	40.83	4600	43.66	4580	41.00	4390	36.00	4290	42.55	4713
1916	101-10	7.33	3910	7.50	3450	12.67	3790	13.50	3290	13.33	3200	8.67	3720	8.17	3760	10.00	4150	6.00	3990	7.67	4140	9.44	3750
1917	301-10	6.50	1860	4.33	1740	4.67	1720	6.67	1600	7.00	1580	3.67	1580	3.50	1540	7.33	2210	6.33	2620	8.33	1800	7.28	1747
1918	201-10	2.50	1750	1.83	1590	1.33	1620	2.17	1670	4.50	1580	2.83	1630	2.83	1630	3.00	1620	3.17	1810	7.67	1840	4.89	1728
1919	101-10	12.00	3680	12.67	3640	8.33	2750	8.50	2990	11.33	3070	12.00	3030	14.33	3540	16.17	3530	14.50	3380	13.33	3200	12.22	3317
1920	301-10	20.33	2930	20.83	3000	20.50	3020	21.67	2950	20.67	1660	21.00	2490	23.67	3130	25.00	3150	17.67	2690	26.00	3190	22.33	2593
1921	201-10	11.67	2150	19.17	1950	10.83	1850	14.00	1660	17.17	2970	10.83	1700	11.00	2590	11.67	2750	10.17	1640	15.43	2580	14.76	2567
1922	101-10	19.67	2970	23.00	2870	26.00	3140	28.83	2670	26.67	2650	24.00	2810	27.67	3040	32.67	3040	29.33	2990	28.00	2470	24.78	2697
1923	301-10	15.33	3830	14.17	3390	19.00	3610	23.33	3100	20.83	2950	18.67	3380	21.67	3200	20.83	3400	14.33	3790	13.17	3010	16.44	3263
1924	201-10	24.17	3250	22.00	3180	19.17	3050	24.67	2570	27.67	2390	18.17	3060	22.67	2790	23.50	2840	19.33	2390	22.17	2570	24.67	2737
1925	101-10	16.00	3790	19.00	3710	21.83	4220	22.50	2950	21.17	3130	16.17	3250	17.17	3570	25.83	2350	21.17	3480	21.83	3090	19.67	3337
1926	301-10	0.33	530	0.50	620	0.33	480	0.33	480	0.67	410	0.50	520	0.17	290	0.17	390	0.17	390	0.33	680	0.44	540
1927	201-10	19.00	3660	22.17	3370	19.50	3230	31.67	1750	22.83	2330	29.17	3200	30.83	2150	34.83	2510	33.83	2220	24.67	2120	22.17	2703
1928	101-10	0.33	2030	0.67	2160	0.50	620	0.50	620	0.50	970	2.00	1780	1.33	1820	1.33	1370	2.83	2480	0.50	1220	0.44	1407
1929	301-10	9.50	1380	7.83	1430	5.83	1200	6.83	1240	9.50	1180	7.17	1470	7.67	990	10.67	1610	16.00	1640	18.50	1990	12.50	1517
1930	201-10	10.17	1490	9.17	1450	7.67	1290	9.00	1360	10.17	1290	10.17	1490	10.00	1250	10.33	1130	10.50	1370	11.17	1580	10.50	1453
1931	101-10	14.00	3710	12.67	3340	13.50	2890	13.33	2650	14.00	2660	12.33	2760	12.17	2870	15.50	3020	14.83	2960	15.33	2430	14.44	2933
1932	301-10	26.50	4510	26.00	3340	32.00	3480	29.00	3810	27.33	3910	21.67	3150	--	--	--	--	--	--	26.92	4210	26.92	4210
1933	201-10	No yield. Failure due to drought.																					
1934	101-10	No yield. Failure due to drought.																					
1935	301-10	16.33	2520	15.33	2280	15.67	2230	16.67	2120	16.33	2010	16.33	2020	14.83	2080	16.50	2210	16.67	2280	18.67	3480	17.11	2670
1936	201-10	No yield. Failure due to drought.																					
TOTAL, 25 Yrs.		293.91	59215	290.36	56050	301.19	53320	332.75	48330	338.24	49570	297.77	52820	--	--	--	--	--	--	346.86	56225	326.33	55004
Average 25 Years		11.76	2369	11.61	2242	12.05	2133	13.31	1933	13.53	1883	11.91	2113	--	--	--	--	--	--	13.87	2249	13.05	2200
TOTAL, 24 Yrs.		267.31	54705	264.36	52710	269.19	49840	303.75	44520	310.91	45660	276.10	49670	289.26	49640	331.82	51165	305.42	53705	319.94	52015	299.41	50794
Average 24 Years		11.14	2279	11.02	2196	11.22	2077	12.66	1855	12.95	1903	11.50	2070	12.08	2066	13.83	2132	12.73	2238	13.33	2167	12.48	2116
Increase over "Av. of None" 24 Yrs.				−1.46	80	−1.26	−39	0.18	−2.61			−0.98	−46	−0.40	−48	1.35	16	0.25	122				
Increase per cent				−11.70	3.78	−10.10	−1.84	1.44	−12.33			−7.85	−2.17	−3.21	−2.27	10.82	0.76	2.00	5.77				

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

Summary: Grain and Straw, 25 Years

Average annual yield from all plots (24 years) ---------- Grain, 735 pounds; Straw, 2099 pounds; Total, 2834 pounds. Grain 12.25 Bu. per acre.
Average annual yield from all plots, No Treatment ---------- Grain, 783 pounds; Straw, 2200 pounds; Total, 2983 pounds. Grain 13.05 Bu. per acre.
Average annual yield from all plots receiving Nitrogen "N" ---------- Grain, 697 pounds; Straw, 2242 pounds; Total, 2939 pounds. Grain 11.61 Bu. per acre.
Average annual yield from all plots receiving Phosphorus "P" ---------- Grain, 723 pounds; Straw, 2133 pounds; Total, 2856 pounds. Grain 12.05 Bu. per acre.
Average annual yield from all plots receiving Potassium "K" ---------- Grain, 799 pounds; Straw, 1933 pounds; Total, 2732 pounds. Grain 13.31 Bu. per acre.

Some hail damage June 25, 1914. Hail damage and wheat stem maggot damage following the hail which occurred July 1, 1928.
The 24 year average does not include the yields for 1932 the record for which is incomplete.

FERTILITY TREATMENT: "N" means 350 pounds Nitrate of Soda; "P" means 200 pounds of 16 per cent acid phosphate; "K" means 200 pounds of "Muriate of Potash" applied per acre. Applications made before corn and wheat only. No "Muriate of Potash" was applied from 1915 to 1918, inclusive; no supply available on account of World War. No fertilizers applied after 1933—no funds. Project closed.

TABLE 30.—Yields of Legume Seed and Straw Following Certain Soil Treatments at Eureka, S. D., Rotation No. 1

Crop	Treatment / Plot No. / Yield / Year	Acre	None −1 Grain Bu.	None −1 Straw Lbs.	N −2 Grain Bu.	N −2 Straw Lbs.	P −3 Grain Bu.	P −3 Straw Lbs.	K −4 Grain Bu.	K −4 Straw Lbs.	None −5 Grain Bu.	None −5 Straw Lbs.	NP −6 Grain Bu.	NP −6 Straw Lbs.	NK −7 Grain Bu.	NK −7 Straw Lbs.	PK −8 Grain Bu.	PK −8 Straw Lbs.	NPK −9 Grain Bu.	NPK −9 Straw Lbs.	None −10 Grain Bu.	None −10 Straw Lbs.	Average of None Grain Bu.	Average of None Straw Lbs.
Peas	1912	301-10	4.67	1220	3.67	1280	1.67	900	2.67	1110	6.67	1600	3.33	1150	2.17	620	2.33	1110	6.50	1860	9.00	1710	6.78	1510
Peas	1913	201-10	No seed. Cut for hay.																					
Peas	1914	101-10	5.67	1500	5.83	1400	3.33	900	3.83	1020	4.67	870	3.67	880	3.17	810	3.83	770	4.17	750	4.17	800	4.84	1057
S.Cl.	1915	301-10	2.50	3060	3.25	2330	2.83	1780	2.67	2200	4.50	2810	4.25	2890	2.42	2440	1.92	1930	3.75	3410	5.00	3950	4.00	3273
S.Cl.	1916	201-10	First cutting chiefly weeds. No second cutting for seed or hay.																					
S.Cl.	1917	101-10	0.92	1275	0.33	265	0.04	345	0.07	345	0.07	445	0.12	595	0.21	435	0.07	395	0.42	720	0.50	560	0.50	760
S.Cl.	1918	301-10	Failure.																					
S.Cl.	1919	201-10	Failure. Seeded to soy beans which also failed on account of drought.																					
S.Cl.	1920	101-10	Failed. Seeded to soy beans which were cut for hay.																					
S.Cl.	*1921	301-10	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414	9.10	1414
S.Cl.	1922	201-10	2.17	3770	2.17	3620	1.50	3410	1.83	3490	2.83	3230	1.50	3560	2.00	3530	1.67	3250	2.50	3700	2.50	4100	2.50	3700
S.Cl.	1923	101-10	6.83	3840	8.00	3770	4.50	2480	4.50	3030	5.17	3390	3.67	3380	4.00	3710	5.17	3640	6.33	3620	6.33	2670	6.11	3300
S.Cl.	1924	301-10	3.50	3800	4.17	3550	2.83	4000	3.50	3650	4.17	3250	4.00	3950	3.67	3800	3.00	4460	3.00	3100	4.17	2900	3.95	3317
S.Cl.	1925	201-10	0.83	1950	0.50	2120	0.17	2140	0.17	2190	0.50	2220	0.33	2880	0.33	2230	0.17	2390	0.33	2680	2.00	2080	1.11	2083
S.Cl.	1926	101-10	5.67	1660	2.17	570	0.17	450	0.50	710	0.33	90	0.67	710	0.17	40	0.00	50	0.33	650	0.17	40	2.06	597
S.Cl.	1927	301-10	6.67	4650	9.00	3860	7.33	3760	9.00	3310	8.33	2700	7.83	3380	5.83	3550	3.00	2870	4.00	3760	4.83	3560	6.61	3637
S.Cl.	1928	201-10	3.00	2220	1.33	1470	0.83	1500	1.00	1490	1.33	1520	0.67	1610	0.83	1600	0.67	1560	0.67	1960	1.67	1900	2.00	1880
S.Cl.	1929	101-10	6.83	3090	3.00	2820	2.00	1580	2.67	1840	1.67	1700	1.83	1990	1.67	2250	1.17	1880	1.67	1950	2.33	1010	3.61	1933
S.Cl.	1930	301-10	No seed harvested from plots 301-308.																0.00	1550	0.00	2150	0.00	717
S.Bn.	†1931	201-10	2.50	550	2.67	490	1.83	490	2.67	540	3.00	670	2.00	430	2.50	450	1.33	370	1.67	350	1.83	440	2.44	553
S.Bn.	†1932	101-10	12.17	1520	13.50	1590	10.00	1150	11.17	1080	11.67	1400	9.67	1020	10.17	1240	9.17	1050	8.67	1230	6.67	1200	10.17	1373
S.Cl.	1933	301-10	Drought. Sweet clover failed. Seeded second time in the spring, but no crop except weeds.																					
S.Cl.	1934	201-10	Killed by drought. Seeded to soy beans—did not come into blossom.																					
S.Cl.	1935	101-10	Failed on account of drought. Reseeded with three pecks of oats May 4, 1935—cut for hay.																					
S.Cl.	1936	301-10	Total failure.																					
Total All Crops			73.03	35519	68.69	30549	48.13	26299	55.35	27419	64.01	27309	52.64	29839	48.24	28119	42.60	27139	53.11	32704	60.27	30484	65.78	31104
AVERAGE: 25 Yrs.			2.92	1421	2.75	1222	1.93	1052	2.21	1097	2.56	1092	2.11	1194	1.93	1125	1.70	1086	2.12	1308	2.41	1219	2.63	1244
Increase over "Av. of None"					0.12	−22	−0.70	−192	−0.41	−147			−0.52	−50	−0.70	−119	−0.93	−158	−0.51	64				
Increase per cent					4.56	−1.77	−26.62	−15.43	−15.59	−11.82			−19.77	−4.02	−26.62	−9.57	−35.36	−12.70	−19.39	5.14				
Total Peas 3 Yrs.			10.34	2720	9.50	4280	5.00	1800	6.50	2130	11.34	2470	7.00	2030	5.34	1430	6.16	1880	10.67	2610	13.17	2510	11.62	2567
AVERAGE: 3 Yrs.			3.45	907	3.17	1427	1.67	600	2.17	710	3.78	823	2.33	677	1.78	477	2.05	627	3.56	870	4.39	837	3.87	856
Increase over "Av. of None"					−0.70	571	−2.20	−256	−1.70	−146			−1.54	−179	−2.09	−379	−1.82	−229	−0.31	14				
Increase per cent					−18.09	66.71	−56.85	−29.91	−43.93	−17.06			−39.79	−20.91	−54.01	−44.28	−47.03	−26.75	−8.01	1.64				
Total Sw. Clover			48.02	30729	43.02	25789	31.30	22859	35.01	23669	38.00	22769	33.97	26359	30.23	24999	25.94	23839	32.10	28514	38.60	26334	41.55	26612
AVERAGE: 22 Yrs.			2.18	1397	1.96	1172	1.42	1039	1.59	1076	1.73	1035	1.54	1198	1.37	1136	1.18	1084	1.46	1296	1.75	1197	1.89	1210
Increase over "Av. of None"					0.07	−38	−0.47	−171	−0.30	−134			−0.35	−12	−0.52	−74	−0.71	−126	−0.43	86				
Increase per cent					3.70	−3.14	−24.87	−14.13	−15.87	−11.07			−18.52	−0.99	−27.51	−6.12	−37.57	−10.41	−22.75	7.11				
Total Soy Beans			14.67	2070	16.17	2080	11.83	1640	13.84	1620	14.67	2070	11.67	1450	12.67	1690	10.50	1420	10.34	1580	8.50	1640	12.61	1927
AVERAGE: 3 Yrs.			4.89	690	5.39	693	3.94	547	4.61	540	4.89	690	3.89	483	4.22	563	3.50	473	3.45	527	2.83	547	4.20	642
Increase over "Av. of None"					1.19	51	−0.26	−95	0.41	−102			−0.31	−159	0.02	−79	−0.70	−169	−0.75	−115				
Increase per cent					28.33	7.94	−6.19	−14.80	9.76	−15.89			−7.38	−24.77	0.48	−12.31	−16.67	−26.32	−17.86	−17.91				

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

* All plots cut together.

† Sweet clover failed. Soy Beans substituted.

LEGUMES

TABLE 31.—Yields of Legume Hay Following Certain Soil Treatments at Eureka, S. D. Rotation No. 1

Treatment / Plot No. / Yield / Crop	Year	Acre	None -1 Lbs.	N -2 Lbs.	P -3 Lbs.	K -4 Lbs.	None -5 Lbs.	NP -6 Lbs.	NK -7 Lbs.	PK -8 Lbs.	NPK -9 Lbs.	None -10 Lbs.	Average of None Lbs.
Peas.	1913	201-10	3250	3050	2900	2800	2800	2800	2800	2500	2800	2700	2917
S.Cl.	1915	301-10	1100	1450	1600	1400	2000	2150	1600	2050	2550	2800	1967
S.Cl.	1917	101-10	3250	3250	2750	3000	3250	3500	4200	4000	4750	4250	3583
*S.Bn.	1920	101-10	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
**Oats.	1935	101-10	3708	3708	3708	3708	3708	3708	3708	3708	3708	3708	3708
Total All Crops			13178	13328	12828	12778	13628	14028	14178	14128	15678	15328	14045
Average: 25 Years			527	534	513	511	545	561	567	565	627	613	562
Increase over "Av. of None"				−28	−49	−51		−1	5	3	65		
Increase per cent				−4.98	−8.72	−9.07		−0.15	0.89	0.53	11.57		
Total Peas: 1 Year			3250	3050	2900	2800	2800	2800	2800	2500	2800	2700	2917
Increase over "Av. of None"				133	−17	−117		−117	−117	−417	−117		
Increase per cent				4.56	−0.58	−4.01		−4.01	−4.01	−14.30	−4.01		
Total Sw. Cl.			4350	4700	4350	440	5250	5650	5800	6050	7300	7050	5550
Average: 22 Years			198	214	198	200	239	257	264	275	332	320	252
Increase over "Av. of None"				−38	−54	−52		5	12	23	80		
Increase per cent				−15.08	−21.43	−20.63		1.98	4.76	9.13	31.75		

NOTE.—The minus (−) sign indicates decrease.

* All plots were cut and weighed together. The weight, 1870 pounds, is the weight for the yield for the whole acre—hence, the average weight for all plots.

** Sweet clover failed and oats were seeded on May 5. Some sweet clover came up in the oats. All plots were cut and weighed together. The weight, 3708 pounds, is the weight for the yield for the whole acre—hence, the average weight for all plots.

Sweet clover was cut for hay in 1915 and 1917 only, after which a seed crop was harvested. Other years no hay crop was removed and the one cutting was for seed.

Summary: Grain, Straw and Hay, 25 Years

Average annual yield from all plots——Grain, 136 pounds; Straw and Hay, 1738; Total, 1874 pounds

Average annual yield from all plots, No Treatment——Grain, 158 pounds; Straw and Hay, 1806; Total, 1964 pounds

Average annual yield from all plots receiving Nitrogen "N"——Grain, 165 pounds; Straw and Hay, 1755; Total, 1920 pounds

Average annual yield from all plots receiving Phosphorus "P"——Grain, 116 pounds; Straw and Hay, 1565; Total, 1681 pounds

Average annual yield from all plots receiving Potassium "K"——Grain, 133 pounds; Straw and Hay, 1608; Total, 1741 pounds

SUMMARY

TABLE 32.—Summary of the Results From All Treatments on All Crops—Corn, Wheat, Legumes—in Rotation No. 1 at Eureka, S. D. Expressed as Weighted Averages

Crop / No. of Yrs. / Treatment	Corn-Grain 24 Yield Bu.	Corn-Grain 24 Gain Bu.	Corn-Stalks 23 Yield Lbs.	Corn-Stalks 23 Gain Lbs.	Wheat-Grain 24 Yield Bu.	Wheat-Grain 24 Gain Bu.	Wheat-Straw 24 Yield Lbs.	Wheat-Straw 24 Gain Lbs.	Legume-Seed 25 Yield Bu.	Legume-Seed 25 Gain Bu.	Legume-Straw 25 Yield Lbs.	Legume-Straw 25 Gain Lbs.	Legume-Hay 25 Yield Lbs.	Legume-Hay 25 Gain Lbs.
None	20.20		2010		12.48		2116		2.63		1244		562	
N	19.01	−1.19	2018	8	11.02	−1.46	2196	80	2.75	**0.12**	1222	−22	534	−28
P	18.38	−1.82	1950	−60	11.22	−1.26	2077	−39	1.93	−0.70	1052	−192	513	−49
K	19.22	−0.98	2046	36	12.66	0.18	1855	−261	2.21	−0.41	1097	−147	511	−51
NP	20.21	**0.01**	2053	43	11.50	−0.98	2070	−46	2.11	−0.52	1194	−50	561	−1
NK	19.54	−0.66	1989	−21	12.08	−0.40	2068	−48	1.93	−0.70	1125	−119	567	5
PK	19.81	−0.39	1960	−50	13.83	**1.35**	2132	16	1.70	−0.93	1086	−158	565	3
NPK	19.65	−0.55	1867	−143	12.73	0.25	22.38	**122**	2.12	−0.51	1308	**64**	627	65

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
N	−5.89	0.40	−11.70	3.78	**4.56**	−1.77	−15.08
P	−9.01	−2.99	−10.10	−1.84	−26.62	−15.43	−21.43
K	−4.85	1.79	1.44	−12.33	−15.59	−11.82	−20.63
NP	**0.05**	**2.14**	−7.85	−2.17	−19.77	−4.02	1.98
NK	−3.27	−1.04	−3.21	−2.27	−26.62	−9.57	4.76
PK	−1.93	−2.49	**10.82**	0.76	−35.36	−12.70	9.13
NPK	−2.72	−7.11	2.00	**5.77**	−19.39	**5.14**	**31.75**

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment. The figures indicating the greatest increase in yield in each crop are printed in bold face type.

GENERAL SUMMARY

TABLE 33.—General Summary of the Results From All Treatments on All Crops: Corn, Wheat, Legumes in Rotation No. 1 Expressed in Terms of the Total Amounts of Dry Matter Produced Per Acre for Twenty-Five Years. Eureka, S. D.

Treatment / Crop	No. Yrs.	None Grain Lbs.	N Grain Lbs.	P Grain Lbs.	K Grain Lbs.	NP Grain Lbs.	NK Grain Lbs.	PK Grain Lbs.	NPK Grain Lbs.
Corn	24	33,939	31,939	30,883	32,289	33,958	32,823	33,272	33,006
Wheat	24	17,965	15,862	16,151	18,225	16,566	17,356	19,909	18,325
Legume Seed	25	3,947	4,121	2,888	3,321	3,158	2,894	2,556	3,187
Total	(73)	55,851	51,922	50,922	53,835	53,682	53,073	55,737	54,518
Total Gain		------	−3,929	−4,929	−2,016	−2,169	−2,778	−114	−1,333
Av. Gain per Yr.		------	−53.8	−67.5	−27.6	−29.7	−38.1	−1.6	−18.3
Gain per cent		------	−7.03	−8.82	−2.97	−3.88	−4.98	−0.21	−2.39

		Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay
Corn	23	46,231	46,410	44,845	47,060	47,210	45,755	45,075	42,945
Wheat	24	50,794	52,710	49,840	44,520	49,670	49,640	51,165	53,705
Legume Straw	25	31,104	30,549	26,299	27,419	29,839	28,119	27,139	32,704
Legume Hay	25	14,045	13,328	12,828	12,778	14,028	14,178	14,128	15,678
Total	(72)	142,174	142,997	133,812	131,777	140,747	137,692	137,507	145,032
Total Gain		------	823	−8,362	−10,397	−1,427	−4,482	−5,490	2,858
Av. Gain per Yr.		------	11.4	−116.1	−144.4	−19.8	−62.3	−76.3	39.7
Gain per cent		------	0.58	−5.88	−7.31	−1.00	−3.15	−3.86	2.01

Total Amount of Dry Matter Produced Under the Several Treatments

	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay
Corn	80,170	78,349	75,728	79,349	81,168	78,578	78,347	75,951
Wheat	68,759	68,571	65,991	62,745	66,236	66,996	71,074	72,030
Legumes	49,096	47,998	42,015	43,518	47,025	45,191	43,823	51,569
Total	198,025	194,919	184,734	185,612	194,429	190,765	193,244	199,550
Total Gain	------	−3,106	−13,291	−12,413	−3,596	−7,260	−5,604	1,525
Av. Gain per Yr.	------	−42.4	−183.6	−172.0	−49.5	−100.4	−77.9	21.4
Gain per cent	------	−1.55	−6.70	−6.28	−1.81	−3.66	−2.84	0.78

General Summary of the Increases in Yield for the Several Treatments Over No Treatment for All Crops Grown

Total Gain Grain 25 Yrs.	−3,929	−4,929	−2,016	−2,169	−2,778	−114	−1,333
Total Gain Straw, etc., 25 Yrs.	823	−8,362	−10,397	−1,427	−4,482	−5,490	2,858
Total Gain Dry Matter	−3,106	−13,291	−12,413	−3,596	−7,260	−5,604	1,525
Gain per cent Grain 25 Yrs.	−7.03	−8.82	−2.97	−3.88	−4.98	−0.21	−2.39
Gain per cent Straw 25 Yrs.	0.58	−5.88	−7.31	−1.00	−3.15	−3.86	2.02
Gain per cent Total Dry Matter	−1.55	−6.70	−6.28	−1.81	−3.66	−2.84	0.78

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
NOTE.—The minus (−) sign indicates decrease.
The average yields per acre per year for None (No Treatment) for all crops were: Grain, 765 lbs.; Straw, etc., 1975 lbs.; total, 2740 lbs.

Part IV
Soil Fertility Investigations at Highmore, S. D.
Complete Fertility Test

Introduction.—The results here reported from the complete fertility tests have been obtained from a project carried on at the Experiment Substation at Highmore, S. D. The project has been supported by funds appropriated biennially by the South Dakota legislature.

History.—The project was begun in 1912 and was in progress until 1936, a period of 25 years, when it was suspended on account of funds to pursue it further.

Object.—Before the project was begun nothing was known of the plant food requirement of the soils of that part of the state (see map on page 3). It was thought that long continued field trials with the application of plant food elements would result in information that would form the basis for soil management practices which would maintain the plant food supply in the soil and perhaps result permanently in more profitable crop yields.

Plan of the Work.—The project is located on six "blocks" of land in the southwest corner of the substation farm, each of which is divided into 10 plots two rods wide and eight rods long. The plots are separated by alleys which have been kept clear of weeds by cultivation. The blocks of 10 plots each are separated by roads.

The general plan of the plots, their numbers, and soil treatments are shown in Figure 40.

Soil.—The soil on which the plots are situated is Williams loam. In the soil survey report for Hyde county, of which Highmore is the county seat, the following description of this soil appears:

"The surface soil of Williams loam, to a depth ranging from 7 to 12 inches and averaging about 8 inches, consists of loose, friable very dark grayish-brown or nearly black loam of finely granular structure. The surface soil is underlain, to a depth varying from 16 to 20 inches, by dark-brown or brown, heavier-texture loam or clay loam which contains some glacial pebbles. The next layer, which reaches a depth of about 30 inches, is friable or slightly compact yellow or grayish-yellow silty clay or clay loam. It is highly calcareous, containing an abundance of lime in streaks and concretions. Some specks of orange or reddish-brown iron oxide may be present in places. Below this layer is pale-yellow or yellow friable silt, the glacial till from which this soil was derived. This material is uniformly calcareous, but the lime streaks are not so abundant as in the layer above. A few iron-oxide stains present. The color of the surface soil is rather uniform throughout the county. However, in cultivated fields the surface soil presents a somewhat lighter color than in the virgin prairie.

"Glacial bowlders of various sizes occur on the surface, and in some areas these rocks are sufficiently numerous to interfere with cultivation. Very few large bowlders are present, but small stone and shale fragments are common, particularly in the less-weathered till."

The Williams loam covers extensive areas east of Missouri River and is an important soil type. No doubt the results obtained from this project at Highmore may be utilized in planning systems of soil management at other places where the Williams loam occurs.

0	101	0	201	0	301	0	401	0	501	0	601
N	102	N	202	N	302	N	402	N	502	N	602
P	103	P	203	P	303	P	403	P	503	P	603
K	104	K	204	K	304	K	404	K	504	K	604
0	105	0	205	0	305	0	405	0	505	0	605
NP	106	NP	206	NP	306	NP	406	NP	506	NP	606
NK	107	NK	207	NK	307	NK	407	NK	507	NK	607
PK	108	PK	208	PK	308	PK	408	PK	508	PK	608
NPK	109	NPK	209	NPK	309	NPK	409	NPK	509	NPK	609
0	110	0	210	0	310	0	410	0	510	0	610

ROTATION NO. 1.

CORN-WHEAT-PEAS & OATS-GRAIN SORGHUM-OATS-ALFALFA: SOIL FERTILITY TEST.

EXPERIMENT SUBSTATION, HIGHMORE, S. DAK.

Fig. 40.—Plan of the Complete Fertility Plots at the Experiment Substatiton at Highmore

The letters indicate the kind of fertilizer applied to the several plots:
O means nothing applied; often referred to as "No Treatment" or "None."
N means nitrogen applied in nitrate of soda at the rate of 350 pounds per acre.
P means phosphorus applied in acid phosphate at the rate of 200 pounds per acre.
K means potassium applied in potassium chloride at the rate of 200 pounds per acre.
Each letter has a uniform meaning whether it occurs alone or in combination with other letters.

Crop Rotation.—The crop rotation employed in this project is a six-year rotation and includes the following crops which follow each other in the order named: Corn, wheat, oats and peas for hay, grain sorghum, oats, and alfalfa. The alfalfa crop regularly occupies the land for five years and is then plowed for corn.

The varieties of crops grown have been as follows:

Corn: 1912, Minnesota 13; 1914-16, S. D. 86; 1916, Alta, S. D. 1095.

Wheat: 1912-14, Red Fife S. D. 67; 1915-16, Kubanka S. D. 75; 1917-33, Acme S. D. 284; 1934-36, Mindum 1160.

Oats for Hay: 1915-34, Swedish Select, S. D. 112; 1935-36, Cole, S. D. 316.

Peas for Hay: Field peas S. D. 14.

Sorghum: 1912-16, Kowliang S. D. 289; 1917-36, Altamont S. D. 655.

Oats for Grain: 1912-14, Swedish Select S. D. 112; 1915-17, Sixty Day S. D. 165; 1918-36, Cole S. D. 316.

Alfalfa: 1912-29, Vale S. D. 22; 1930-31, Common S. D. 12; 1932-35, S. D. 22; 1936, Cossack Certified 553.

Soil Preparation.—The soil is fall plowed seven inches deep ahead of corn. Corn stubble is disked ahead of spring wheat. Wheat stubble is fall plowed five inches deep ahead of peas and oats for hay. Oats and peas stubble is fall plowed six inches deep ahead of sorghum. Sorghum stubble is disked in the spring ahead of the oats crop. Disking and harrowing are done as the conditions demand to prepare a proper seed bed.

Plant Food Applications.—No organic matter has been returned to the soil except the crop stubbles which have been plowed or disked under.

Nitrogen has been applied in the form of nitrate of soda at the rate of 350 pounds per acre.

Phosphorus has been applied in the form of acid phosphate at the rate of 200 pounds per acre.

Potassium has been appled in the form of potassium chloride at the rate of 200 pounds per acre.

Applications of fertilizers have been made broadcast in the spring before disking on all plots except those in alfalfa. No fertilizer is applied while the plots are in alfalfa.

Applications of potassium were suspended during the World War as no potassium was available.

Harvesting Crops.—All plots have been harvested and threshed separately and the yields of seed, grain, straw and hay carefully weighed and permanently recorded.

Yields.—In the following tables the yields of the several crops for each grown and the average yields for each crop and for all crops for the entire period of 25 years are recorded. A careful study of these data will reveal many facts not included in this necessarily brief discussion.

Corn—Table 34 is a record of all corn yields and shows that for the 25-year period the average yields of corn following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	15.63		
Nitrogen	14.57	−1.06	−6.78
Phosphorus	14.93	−0.70	−4.48
Potassium	14.55	−1.08	−6.91
Nitrogen and phosphorus	15.42	−0.21	−1.34
Nitrogen and potassium	14.43	−1.20	−7.68
Phosphorus and potassium	14.74	−0.89	−5.69
Nitrogen, phosphorus and potassium	14.44	−1.19	−7.61

The minus sign (−) indicates decrease.

It appears from these data the yields following all soil treatments are lower than the yield from the plots receiving no treatment. On this basis no fertilizer can be recommended for corn under the conditions which prevailed at Highmore during the 25 years the project was in progress.

The yields of corn stalks are also shown in Table 34. The comparative yields of both corn and corn stalks are shown graphically in Figure 41.

Wheat—Table 35 is a record of all wheat yields and shows that for the 25-year period the average yields of wheat following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	14.11		
Nitrogen	13.51	−0.60	−4.25
Phosphorus	14.84	0.73	5.17
Potassium	14.54	0.43	3.05
Nitrogen and phosphorus	14.29	0.18	1.28
Nitrogen and potassium	13.78	−0.33	−2.34
Phosphorus and potassium	14.36	0.25	1.77
Nitrogen, phosphorus and potassium	13.89	−0.22	−1.56

The minus sign (−) indicates decrease.

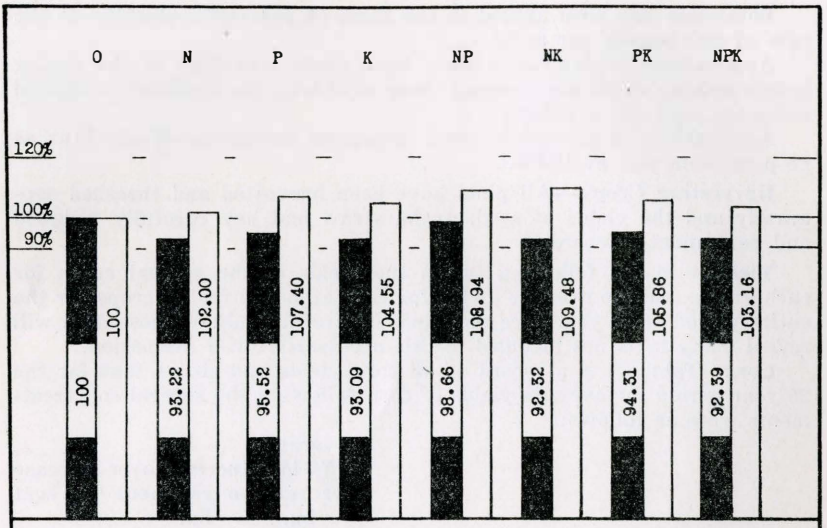

FIG. 41.-CORN YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

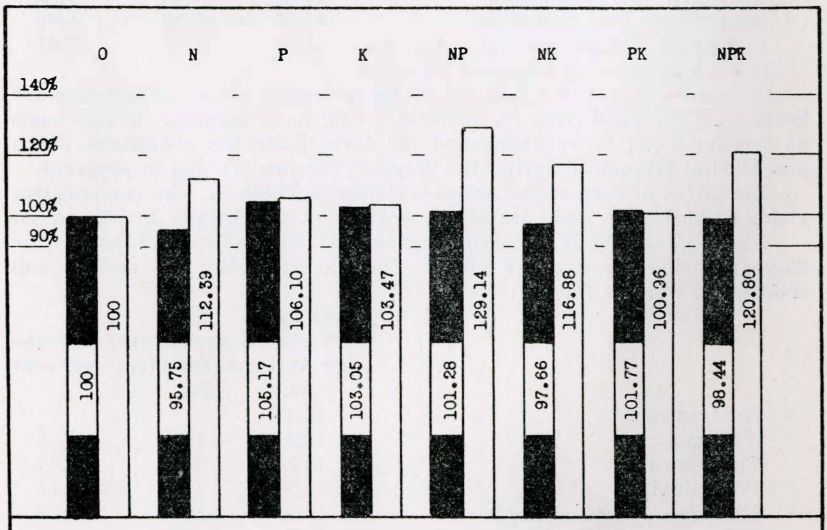

FIG. 42.-WHEAT YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED.

There has been no great difference in the yields following the several treatments although the greatest increase, 5.17 per cent, followed the application of phosphorus.

The yields of wheat straw are also recorded in Table 35. The comparative yields of wheat and wheat straw following the several treatments are shown graphically in Figure 42.

Peas and Oats for Hay.—Table 36 is a record of all the yields of peas and oats for hay following the several soil treatments and shows that for the 22 years the average yields per acre following the several soil treatments are as follows:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	1,990		
Nitrogen	2,408	418	21.01
Phosphorus	2,206	216	10.85
Potassium	1,982	–8	–0.40
Nitrogen and phosphorus	2,787	797	40.05
Nitrogen and potassium	2,368	378	18.99
Phosphorus and potassium	2,115	125	6.28
Nitrogen, phosphorus and potassium	2,770	780	39.20

The minus sign (–) indicates decrease.

The outstanding facts shown in this summary are:

1. All treatments, except potassium alone, were followed by increases in yield.
2. Wherever nitrogen was applied, either alone or in combination with other elements there was a substantial increase in yield.
3. Phosphorus alone increased the yield only 10.85 per cent and nitrogen alone 21.01, but the two when applied together increased the yield over no treatment by 40.05 per cent.

The comparative yields of oats and peas for hay are graphically shown in Figure 43.

Sorghum.—Table 37 is a record of all yields of grain sorghum and shows that for the 25-year period the average yields following the several soil treatments were as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	10.70		
Nitrogen	11.54	0.84	7.85
Phosphorus	11.20	0.50	4.67
Potassium	9.99	–0.71	–6.64
Nitrogen and phosphorus	12.09	1.39	12.99
Nitrogen and potassium	10.90	0.20	1.87
Phosphorus and potassium	11.06	0.36	3.36
Nitrogen, phosphorus and potassium	11.32	0.62	5.79

The minus sign (–) indicates decrease.

The outstanding facts shown in this summary are:

1. All soil treatments except potassium alone were followed by yields of grain sorghum larger than the yield following no treatment.

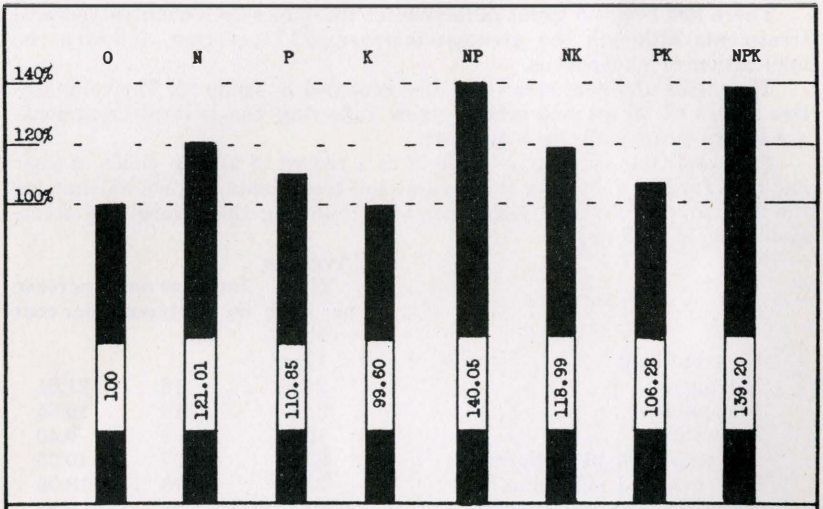

FIG. 43.–OATS AND PEAS HAY YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. YIELDS AFTER NO TREATMENT 100.

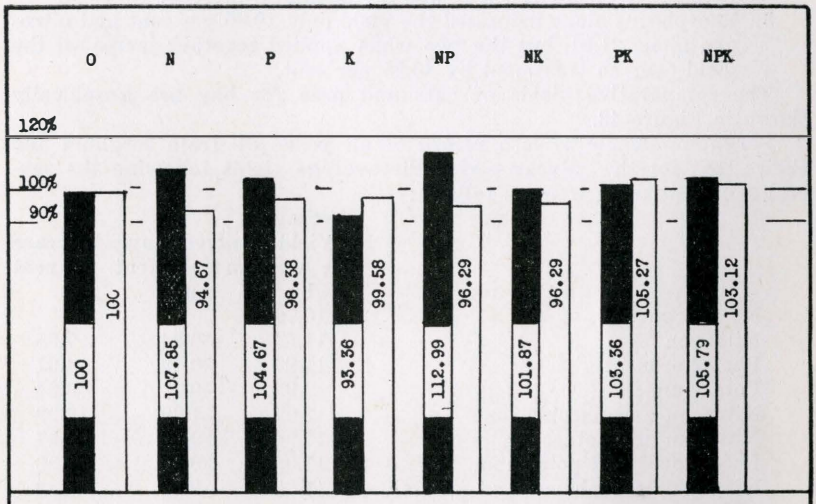

FIG. 44.–SORGHUM YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STALK YIELDS UNSHADED.

2. Wherever potassium was applied the yield was depressed below what the yield was where it was not applied.
3. Nitrogen alone produced an increase of 7.85 per cent, the largest for a single element; phosphorus produced alone an increase of only 4.67 per cent; where the two were combined the increase was 12.99 per cent, the largest for any treatment.

The yields of sorghum stalks are also recorded in Table 37. The comparative yields of both sorghum grain and stalks are shown graphically in Figure 44.

Oats—Table No. 38 is a record of all the yields of oats and shows that for the period of 25 years the average yields of oats following the several soil treatments are as follows:

	Average Yield per Acre bu.	Increase over no treatment bu.	Increase per cent
No treatment	31.83		
Nitrogen	34.70	2.87	9.02
Phosphorus	32.85	1.02	3.20
Potassium	30.32	–1.51	–4.74
Nitrogen and phosphorus	36.16	4.33	13.60
Nitrogen and potassinm	34.93	3.10	9.74
Phosphorus and potassium	34.80	2.97	9.33
Nitrogen, phosphorus and potassium	35.47	3.64	11.44

The minus sign (–) indicates decrease.

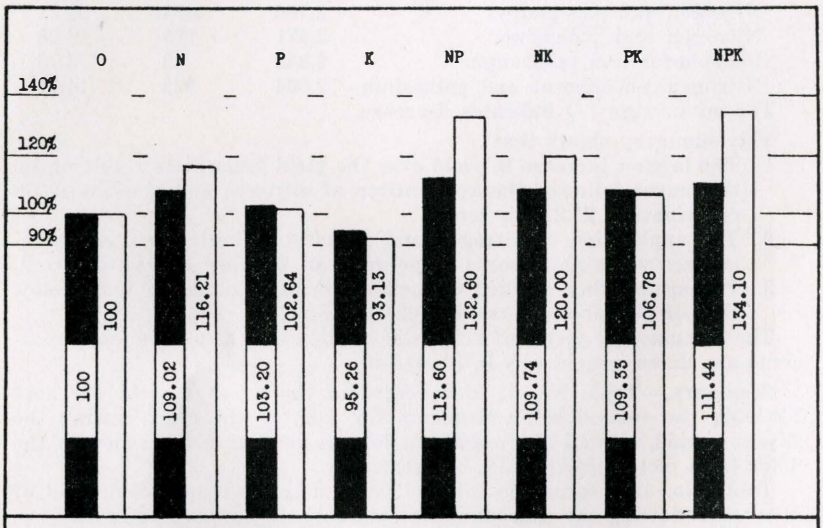

FIG. 45.–OATS YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. YIELDS AFTER NO TREATMENT 100. GRAIN YIELDS SHADED; STRAW YIELDS UNSHADED.

The outstanding facts shown in this summary are:

1. Nitrogen alone was followed by a larger increase in yield than any other single element, 9.02 per cent.
2. Phosphorus alone was followed by the next highest increase for a single element, 3.20 per cent.
3. Potassium alone decreased the yield.
4. Nitrogen and phosphorus combined gave the highest increase of any treatment, 13.60 per cent.

The yields of oat straw are also recorded in Table 38.

The comparative yields of both oats and straw are shown graphically in Figure 45.

Alfalfa Seed—Alfalfa was cut for seed only 3 years out of a possible 24 years and the yields are recorded in Table 39. The averages are computed on the basis of 24 years.

The comparative yields of both seed and straw are shown graphically in Figure 46.

Alfafa Hay—Table No. 40 is a record of all yields of alfalfa hay and shows that for the 24 years the average yields following the several soil treatments have been as follows:

	Average Yield per Acre lbs.	Increase over no treatment lbs.	Increase per cent
No treatment	2,282		
Nitrogen	2,228	–54	–2.37
Phosphorus	2,419	137	6.00
Potassium	2,188	–94	–4.15
Nitrogen and phosphorus	2,766	484	21.21
Nitrogen and potassium	2,471	189	8.28
Phosphorus and potassium	2,345	63	2.76
Nitrogen, phosphorus and potassium	2,604	322	14.11

The minus sign (–) indicates decrease.

This summary shows that:

1. The largest increase in yield over the yield from plots receiving no treatment followed the applicatiton of nitrogen and phosphorus in combination, 21.21 per cent.
2. The application of nitrogen and potassium singly resulted in decreases while phosphorus alone gave an increase of 6.00 per cent.
3. Potassium when applied with phosphorus reduced the yield below that of phosphorus alone by 3.24 per cent.

The comparative yields of alfalfa hay following the several soil treatments are shown graphically in Figure 46.

Summary.—Table No. 41 is a record of the average yield per acre following the several soil treatments for each of the crops during the 25-year period, as well as the gain or loss in yield as compared with the yields from plots receiving no soil treatment.

Table No. 42 records the total yields and the average total yield of all crops following the several soil treatments, the average gain or loss, and the average increase or decrease per cent of yields as compared with the average total yield from all plots receiving no treatment.

The comparative yields of all dry matter harvested following the several soil treatments are shown graphically in Figure 47 and Figure 48.

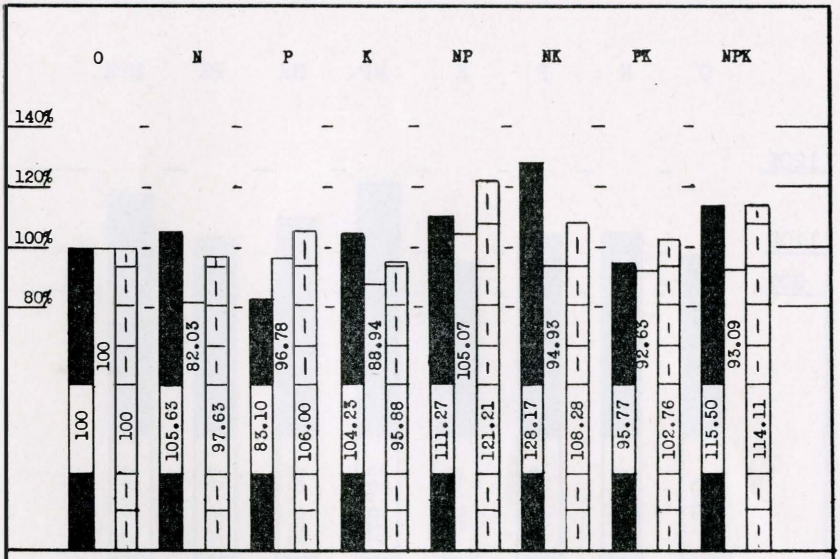

FIG. 46.-LEGUME YIELDS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. D. YIELDS AFTER NO TREATMENT 100. SEED YIELD SHADED; STRAW YIELD UNSHADED; HAY BARRED.

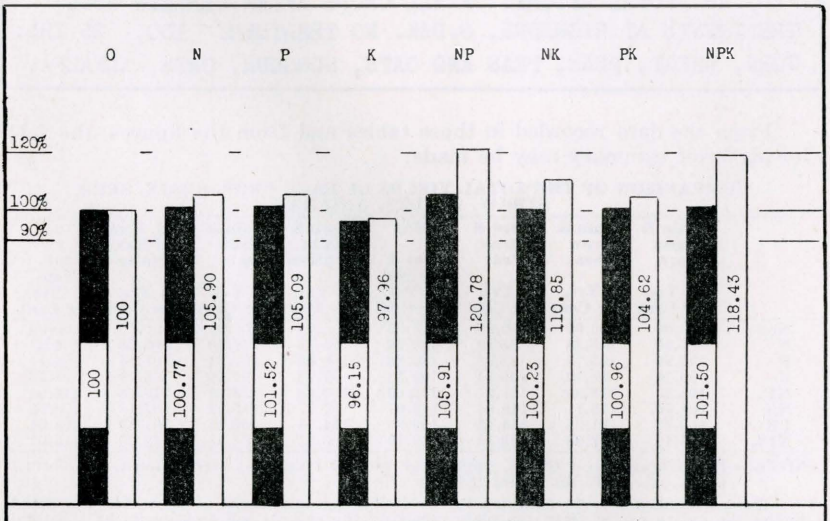

FIG. 47.-COMPARATIVE TOTAL WEIGHTS OF SEEDS AND STRAW, STALKS, AND HAY OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S. DAK. NO TREATMENT 100. SEED YIELDS SHADED. STRAW, STALKS, AND HAY YIELDS UNSHADED.

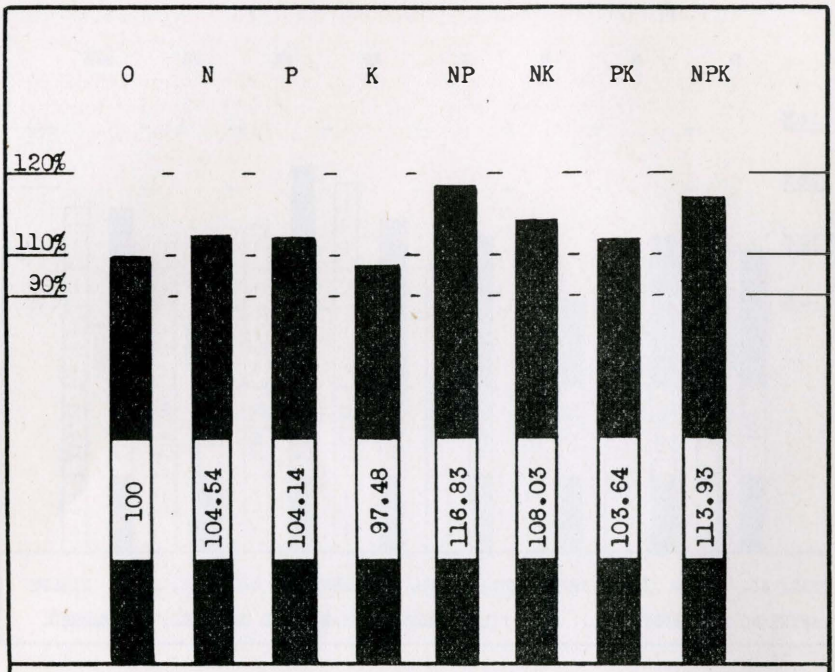

FIG. 48.-TOTAL WEIGHTS OF ALL CROPS AFTER CERTAIN SOIL TREATMENTS AT HIGHMORE, S.DAK. NO TREATMENT 100. 25 YRS. CORN, WHEAT, PEAS, PEAS AND OATS, SORGHUM, OATS, ALFALFA.

From the data recorded in these tables and from the figures, the following brief summary may be made:

COMPARISON OF THE TOTAL YIELDS OF EACH CROP, GRAIN, SEED, STRAW, STALKS, AND HAY

	Grain & Stalks Corn 25 Yrs. Per Cent	Grain & Straw Wheat 25 Yrs. Per Cent	Seed & Straw Peas 3 Yrs. Per Cent	Hay Peas & Oats Hay 22 Yrs. Per Cent	Grain& Stalks Sorghum 25 Yrs. Per Cent	Grain & Straw Oats 25 Yrs. Per Cent	Seed, Straw and Hay Alfalfa 24 Yrs. Per Cent	All Crops 25 Yrs. Per Cent
None	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N	97.90	106.53	88.19	120.98	98.15	112.80	96.36	104.54
P	101.85	105.77	95.96	110.86	100.06	102.91	105.14	104.14
K	99.19	98.83	103.34	99.58	97.93	94.10	95.29	97.48
NP	**104.13**	**118.50**	117.33	**140.03**	100.68	**123.60**	**119.78**	**116.83**
NK	101.46	110.11	119.66	118.97	97.77	115.12	107.18	108.03
PK	100.45	101.25	**144.13**	106.30	**104.78**	106.51	101.84	103.64
NPK	98.12	112.93	130.15	139.19	103.82	123.35	112.30	113.93

NOTE.—The average yield of all crops after no soil treatment were: grain, 703 lbs.; straw, etc., 1665 lbs. ; total 2368 lbs.

(These percentages were obtained by dividing the total weight of each crop harvested during the entire period from the plots receiving the several soil treatments by the total weight of dry matter produced on the no treatment plots during the entire period.)

From this summary it appears that:

1. The treatment producing the highest yield in the crop rotation was

nitrogen and phosphorus, 116.83 per cent. The next highest was following nitrogen, phosphorus and potassium, 113.93 per cent.

2. Nitrogen and phosphorus produced a little more than a four per cent increase each when applied alone, but when applied together the increase was about four times as great as when each was applied alone.

3. Potassium singly and in combination, except when with nitrogen alone, depressed the yield.

4. The application of nitrogen and phosphorus resulted in the highest yields for corn, wheat, peas and oats hay, oats, and alfalfa. The highest yield for peas, grown only three years and for sorghum followed phosphorus and potassium in combination.

Precipitation.—The precipitation record for Highmore, South Dakota, from 1899 to 1937, a period of 39 years, is shown in Plate IV. The average annual precipitation—rain and melted snow—has averaged 17.258 inches and the total precipitation for the entire period has been 56 feet 1.08 inches.

Wide variation in the rainfall from year to year has occurred and this variation has had a notable effect upon the crop yields. The annual rainfall throughout the period is shown graphically in Figure 50 and the average monthly rainfall is similarly illustrated in Figure 49.

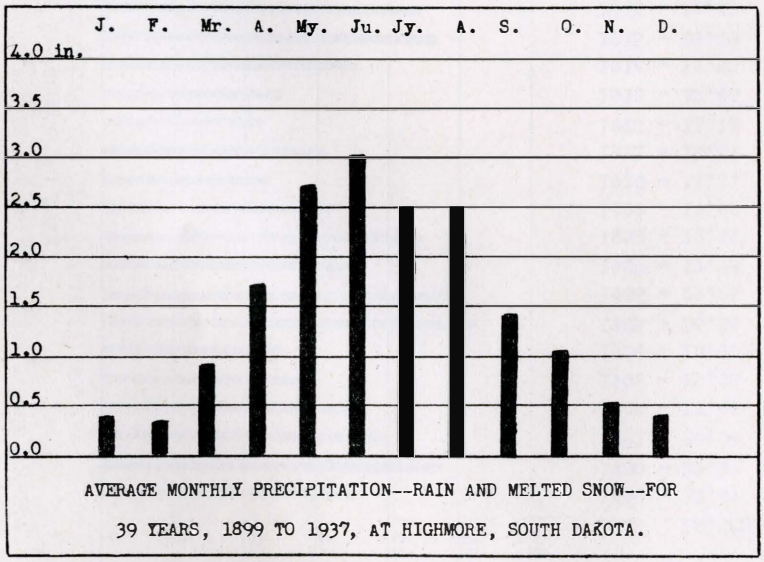

Fig. 49.—The Average Precipitation by Months at Highmore, S. D.

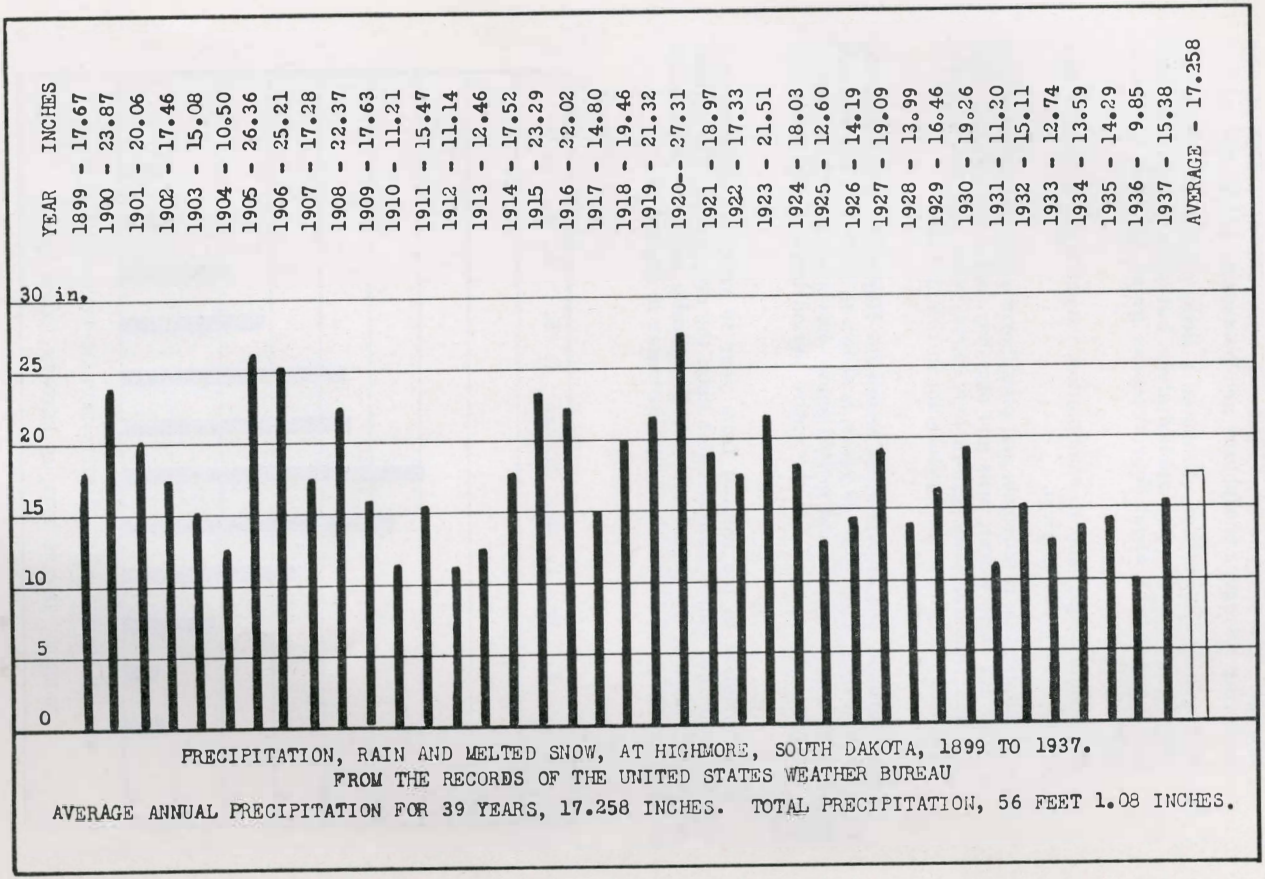

Fig. 50.—The Annual Precipitation at Highmore, S. D.

PRECIPITATION RECORD, HIGHMORE, S.D.

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1887			3.50						4.60				
1888							5.79	3.10					
1889													
1890	0.30	0.20*	0.50	0.19	0.83	6.17	0.36	0.56	0.45	0.32	0.30	0.30	10.28
1891	.00	T	.83	1.94			.72	.80					
1892							1.20	1.17	1.10	.75	.20	.20	
1893	.15	.15		3.85	1.90	2.55	2.64		T				
1894	.45	.05	2.20	.98	.33	5.91	.42	.01	.10	1.63	T	T	12.38
1895	.20	T	.74	2.08	1.66	3.73	.86	1.06	.70	.72	1.15	.00	12.40
1896	T	.30	.85	2.50	.95	2.28	6.67						
1897	.60	.80	2.57	3.44	.86	2.79	3.75	1.45	.41	1.16	.48	.40	18.71
1898	T	.01	1.40	1.51	4.17	1.67	2.33	.62					
1899	.45	.15	1.50	2.00	3.75	4.20	1.81	2.19	.48	.84	.03	.27	17.67
1900	T	.06	1.75	3.20	.47	2.53	2.69	7.56	4.39	.70*	.20*	.32	23.87
1901	.30	.05	.60	1.00	.72	5.33	2.68	2.34	3.93	1.95*	.16*	.40*	20.06
1902	.18*	.22*	2.56*	1.28*	1.37*	4.95*	1.62*	3.20	.40	.20	.38*	1.10	17.46
1903	.05	.30	.87	.70	.85	2.33	3.58	2.40	1.46	.66	.65	.63	15.08
1904	.15	.17	.05	1.43	.99	2.25	2.40	1.48	.38	.60	T	.60	10.50
1905	.60	T	.60	1.39	5.23	5.64	5.54	3.56	.56	1.95	1.29	T	26.36
1906	.30	.40	.80	2.30	5.90	2.50	1.13	6.74	2.81	2.41	.36	.40	25.21
1907	1.00	.40	1.10	.68	5.11	1.62	3.64	.28	1.94	1.96	.05	.40	17.28
1908	.10	.93	.80	1.55	2.68	5.78	2.49	3.53	.62	2.13	1.39	.31	22.37
1909	.26	.34	.13	.30	4.72	1.69	1.81	3.92	1.70	1.04	.71	1.01	17.63
1910	.82	.19	.58	1.40	1.90	3.74	.85	.66	.89	.24	.40	.44	11.21
1911	.11	.39	.32	2.54	1.91	.09	2.69	2.52	3.06	1.05	.35	.44	15.47
1912	.13	.11	.27	1.05	2.20	1.31	1.44	3.39	.71	.18	.00	.35	11.14
1913	.05	.30	.87	1.27	4.56	.97	1.79	1.20	.53	.61	.03	.28	12.46
1914	.13	.62	.45	3.65	2.23	4.09	2.01	1.16	1.01	1.92	T	.25	17.52
1915	.43	1.28	.37	2.50	3.48	4.87	5.55	.78	2.36	1.15	.32	.20	23.29
1916	1.40	.27	.74	.89	4.15	4.54	2.00	4.10	2.75	.58	.13	.47	22.02
1917	1.12	.52	1.27	2.79	2.04	2.04	1.91	.68	2.03	.06	.07	.27	14.80
1918	.60	.25	.67	2.57	3.57	1.59	5.26	1.88	.62	.49	1.10	.86	19.46
1919	.10	1.35	1.24	1.96	6.63	1.90	2.65	.82	.54	2.18	1.80	.15	21.32
1920	.50	.33	1.20	2.56	6.04	7.35	3.56	2.47	1.51	.75	.84	.20	27.31
1921	.25	T	.49	1.78	2.60	.55	3.10	3.68	4.79	1.20	.33	.20	18.97
1922	.45	.93	1.05	.93	2.87	3.65	2.85	.41	.48	.53	2.83	.35	17.33
1923	.42	.01	1.01	1.63	2.04	5.15	3.81	5.00	1.17	.87	.21	.13	21.51
1924	.07	.58	1.63	1.40	.50	5.66	2.11	1.13	2.69	1.10	.34	.82	18.03
1925	.60	.21	.08	1.30	1.08	5.39	.70	1.69	.71	.12	.20	.52	12.60
1926	1.56	T	.02	.16	1.96	1.50	2.53	2.09	1.07	2.78	.16	.36	14.19
1927	.21	.08	.85	3.55	5.80	2.22	1.04	1.77	1.47	.83	.71	.76	19.09
1928	.04	.22	.48	1.11	.96	2.94	2.50	2.32	.76	1.66	.91	.09	13.99
1929	.67	.22	1.75	2.76	1.89	1.71	.69	1.55	1.76	3.08	.33	.05	16.46
1930	.17	1.36	.34	2.90	4.37	2.48	.55	2.45	.74	2.69	.81	T	19.26
1931	.10	.11	1.98	.68	1.60	1.75	.38	.56	1.53	.75	.83	.93	11.20
1932	.12	.08	.80	1.60	2.82	3.31	1.52	1.75	2.11	.88	T	.12	15.11
1933	.05	.20	1.83	1.45	2.72	1.38	1.44	1.36	1.34	.05	.06	.88	12.74
1934	T	.10	.76	.27	.39	2.73	4.33	1.05	1.12	1.76	.46	.22	13.59
1935	.08	.82	2.03	5.13	1.36	1.89	.19	1.54	.25	.13	.55	.52	14.29
1936	.32	.43	.72	.99	1.27	.56	.18	3.30	.30	.50	1.02	.26	9.85
1937	.82	.35	1.50	1.28	3.75	2.91	3.52	.49	.14	.01	.20	.61	15.58
AV.**	.58	.57	.95	1.74	2.74	3.03	2.52	2.28	1.44	1.09	.52	.41	17.258

* Interpolated.
**The average is for the period 1899 to 1937—39 years.
T indicates trace of precipitation, less than .01 inch.

Plate IV.—The Monthly and Annual Precipitation at Highmore, S. D.

During the period of soil fertility trials, 1912 to 1936, the average annual rainfall has been 16.701 inches and the total is 34 feet 9.53 inches.

The weight of one inch of water over an acre is 226,350 pounds. Under the average annual rainfall of 16.701 inches each acre has received as a yearly average 3,780,271 pounds of water.

The average yearly amount of dry matter as an average of all crops grown on plots receiving no treatment has been 2308 pounds. To produce one pound of dry matter 1638 pounds of water has been required. In the case of crops grown on plots receiving soil treatments which have produced higher yields the rainfall required to produce a pound of crop has been correspondingly less. The requirements for the several crops is as follows:

Pounds of water in the form of rain and snow required to produce a pound of dry matter on soil receiving no treatment at Highmore, 1912-36:

Crop:	Water required to produce one pound of crop:
Corn	1,581 lbs.
Wheat	1,572
Sorghum	1,667
Oats	1,755
Peas and Oats Hay	1,946
Alfalfa Hay Crop	1,657
Average for all dry matter harvested	1,638

If the annual precipitation falling on a soil is known for a long period of time and if carefully weighed crop yields have been recorded for the same period it seems possible to estimate the probable productivity of the soil in that region and to formulate farm programs which may be permanent.

Conclusion.—From all the results obtained during the 25-year period it may be concluded that under the soil and climatic conditions, nitrogen and phosphorus are limiting elements in crop production and that the application of these two elements to the soil may be expected to increase the yield approximately 17 per cent.

Whether or not this can be done with profit depends upon costs of fertilizers and prices of farm products.

Reduction in the supply of nitrogen and phosphorus in the soil by crop removal may in the future cause the effect of nitrogen and phosphorus applied to be more notable. There seems to be no good reason for applying potassium to the soil. Wherever potassium was applied, either singly or in combination, the yield was less than it would have been without potassium, except when combined with nitrogen alone.

TABLE 34.—Yields of Corn Following Certain Soil Treatments at Highmore, S. Dak.
Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	201-10	16.28	1340	12.86	1340	9.71	1540	16.43	1230	18.14	1220	12.29	1240	12.00	1220	16.14	1460	17.86	1360	23.14	1180	19.19	1247
1913	601-10	9.79	300	8.31	300	8.21	380	8.89	350	9.40	400	13.56	380	12.70	370	8.49	340	8.76	300	10.13	350	9.77	350
1914	501-10	7.86	1630	5.00	1970	5.00	1790	2.86	1740	11.71	1760	6.71	1820	8.57	1700	10.00	1800	6.29	1700	5.14	1900	8.24	1763
1915	401-10	28.71	1400	30.43	1640	34.00	1780	32.22	1640	33.86	1560	38.28	1870	37.57	1840	35.14	1860	37.21	1840	31.78	1750	31.45	1570
1916	301-10	22.28	1200	33.00	1780	36.71	1880	34.43	1830	31.71	1650	31.86	1830	27.00	1780	25.14	1660	25.14	1650	27.71	1530	27.23	1460
1917	201-10	21.43	1120	21.71	1260	18.71	1290	23.00	1390	22.14	1410	18.86	1220	20.00	1240	17.86	1360	22.14	1510	21.43	1400	21.67	1310
1918	101-10	38.21	1800	37.93	1900	37.57	1950	33.36	1820	34.50	1550	35.07	2140	34.86	2080	34.28	2150	34.14	2200	35.57	2100	36.09	1817
1919	501-10	26.19	1300	26.11	1290	25.68	1290	22.18	1360	28.07	1390	22.78	1220	27.76	1440	27.57	1360	23.47	1210	26.43	1340	26.09	1343
1920	401-10	33.50	1060	36.24	1160	39.21	1170	25.28	940	34.78	980	44.57	1160	42.22	1100	39.36	1110	44.14	1250	39.36	1140	35.88	1060
1921	301-10	7.29	1690	3.86	1650	10.14	1840	9.43	1860	12.29	1760	6.86	1730	0.00	1720	0.00	1730	1.00	1670	1.43	1870	7.00	1773
1922	201-10	43.43	1450	38.00	1000	37.28	1350	41.43	1350	45.00	1250	38.00	1350	36.86	1100	40.57	1500	39.28	1300	45.28	1400	44.57	1367
1923	101-10	39.00	1340	40.14	1620	40.86	1860	41.43	1770	41.43	1450	43.57	1420	34.00	1920	41.43	1900	39.57	1600	37.71	1790	39.28	1527
1924	601-10	10.71	1680	13.86	1600	15.14	1950	10.71	2180	15.57	1830	17.86	1600	13.14	1750	10.86	1750	10.86	1570	15.43	1630	13.90	1713
1925	401-10	11.43	1460	0.00	1750	0.00	2200	3.57	1350	10.00	1340	0.00	1700	0.00	1650	5.29	1480	0.00	1920	3.86	1150	9.10	1317
1926	301-10	0.00	1100	0.00	1000	0.00	1040	0.00	1070	0.00	1080	0.00	1040	0.00	1000	0.00	1050	0.00	1200	0.00	1200	0.00	1127
1927	201-10	35.71	1700	31.00	1930	32.86	1900	34.57	1880	33.57	1900	29.43	2240	28.86	1980	32.43	1930	30.71	2100	34.28	2100	34.52	1900
1928	101-10	5.14	1830	3.71	2300	2.29	2020	2.29	2030	2.14	1950	1.57	1920	1.43	1950	1.43	2180	1.71	1530	3.14	1950	3.47	1910
1929	601-10	0.00	1450	0.00	1650	0.00	1320	0.00	1350	0.00	1600	0.00	1850	0.00	1800	0.00	1400	0.00	1600	0.00	1050	0.00	1367
1930	501-10	14.93	1050	16.28	950	16.07	1000	16.71	1250	17.00	1100	17.71	1200	17.00	1250	18.28	1300	15.28	1200	15.36	1050	15.76	1067
1931	301-10	0.00	390	0.00	290	0.00	470	0.00	460	0.00	280	0.00	270	0.00	210	0.00	370	0.00	410	0.00	400	0.00	357
*1932	201-10	5.71	--	0.43	--	0.00	--	0.14	--	0.00	--	0.00	--	0.00	--	0.00	--	0.00	--	0.57	--	2.09	--
1933	101-10	0.00	1600	0.00	1245	0.00	1150	0.00	950	0.00	650	0.00	650	0.00	750	0.00	500	0.00	800	0.00	800	0.00	1017
1934	601-10	0.00	300	0.00	300	0.00	700	2.14	1150	2.29	2300	3.14	2600	2.57	2500	0.00	1100	0.00	600	0.00	850	0.76	1150
1935	501-10	4.29	1770	5.36	1820	3.86	1570	2.71	1600	5.00	1570	3.36	1450	4.21	1720	4.29	1670	3.50	1600	4.50	1500	4.60	1613
1936	401-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
25 Year Average		15.28	1248	14.57	1323	14.93	1393	14.55	1356	16.34	1333	15.42	1413	14.43	1420	14.74	1373	14.44	1338	15.29	1310	15.63	1297
Increase over "Av. of None"				−1.06	26	−0.70	96	−1.08	59			−0.21	116	−1.20	123	−0.89	76	−1.19	41				
Increase per cent				−6.78	2.00	−4.48	7.40	−6.91	4.55			−1.34	8.94	−7.68	9.48	−5.69	5.86	−7.61	3.16				

NOTE.—The minus (−) sign indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
* No stalks harvested in 1932. In computing the average yield of grain, 25 years was used; for stalks, 24 years.

TABLE 35.—Yields of Wheat Following Certain Soil Treatments at Highmore, S. D.
Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		-1		-2		-3		-4		-5		-6		-7		-8		-9		-10			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	301-10	0.77	560	0.25	765	0.75	905	0.90	716	0.67	710	0.35	880	0.21	540	0.10	540	0.06	560	0.09	495	0.51	588
1913	201-10	7.17	1170	4.33	910	3.83	810	6.33	920	5.00	850	3.08	745	3.83	750	4.25	865	4.58	895	4.67	720	5.61	913
1914	601-10	11.00	2330	9.17	2010	10.33	2290	9.67	2230	9.50	2480	10.00	2860	9.50	2510	10.33	2410	9.33	2410	8.50	2200	9.67	2337
1915	501-10	30.83	4150	30.50	3950	31.83	3700	30.33	3880	26.83	3800	26.17	4450	28.00	3800	27.33	3200	31.17	4150	30.00	3650	29.22	3867
1916	401-10	19.00	2400	15.17	2900	18.67	3200	18.00	2400	18.33	2000	17.17	3350	15.00	2600	21.33	2700	16.00	3400	18.33	2750	18.55	2383
1917	301-10	18.83	2070	16.83	2050	21.33	1780	18.33	1530	17.83	1620	20.17	2380	17.67	2940	18.83	1740	18.83	2070	18.50	1750	18.39	1813
1918	201-10	33.00	2720	24.50	2730	22.00	2030	28.17	2460	27.50	2500	19.83	2110	22.00	2580	22.33	1960	20.50	2220	24.67	1970	28.39	2397
1919	101-10	16.00	1540	17.83	2130	20.83	2300	20.17	2140	21.17	2130	17.67	2290	20.50	2250	21.83	2390	18.50	2270	22.83	2230	20.00	1967
1920	501-10	23.17	2490	26.33	3360	25.00	2340	28.17	2730	24.83	2730	26.67	3300	27.50	3580	25.00	2550	28.17	3410	25.17	2746	24.39	2653
1921	401-10	10.08	1125	8.42	1075	10.00	1450	10.50	1070	10.50	1120	7.00	1160	9.25	1195	12.50	1450	7.33	1510	9.17	1120	9.92	1122
1922	301-10	32.33	2310	30.00	2600	38.00	2620	32.00	2180	33.17	2360	37.33	3210	29.00	2460	30.33	2390	31.83	2690	32.33	2330	32.61	2333
1923	201-10	23.50	2520	27.83	3130	26.17	2130	22.50	1850	25.17	2310	30.50	3320	31.00	3240	27.83	2080	32.50	3350	25.67	2010	24.78	2280
1924	101-10	22.50	2260	25.00	3250	26.17	2330	21.33	930	21.33	2000	25.67	3210	23.33	2750	22.50	1780	22.67	3040	20.67	1970	21.50	2077
1925	601-10	16.00	2260	16.00	2170	18.83	2770	18.17	2660	18.50	3090	18.17	3460	19.00	2910	17.00	2480	17.83	2580	16.67	2230	17.06	2527
1926	401-10	4.42	785	1.92	535	2.50	700	2.50	600	2.92	675	1.17	720	1.17	530	2.08	625	2.08	1025	3.75	695	3.70	718
1927	301-10	21.17	1480	22.00	1860	24.83	1560	23.33	1350	21.50	1360	24.00	2210	22.33	1960	25.75	1905	26.33	2510	24.33	1830	22.33	1557
1928	201-10	11.25	805	12.17	1350	11.17	1060	15.17	1290	15.67	1110	14.08	1765	11.83	1780	13.00	1010	11.50	2010	14.17	1050	13.70	988
1929	101-10	12.83	1080	14.00	1810	15.33	1380	12.50	1150	12.17	1140	13.17	2310	11.50	1560	13.17	1260	11.17	2030	12.67	1240	12.56	1153
1930	601-10	16.33	1430	17.17	1630	19.50	1780	20.33	1580	20.50	1820	27.17	2070	24.33	1940	20.50	1720	21.67	1900	16.83	1410	17.87	1553
1931	501-10	0.80	522	0.85	619	1.17	640	1.25	525	1.08	515	0.82	551	1.45	613	1.97	802	1.22	657	1.50	710	1.13	582
1932	301-10	13.67	1880	9.33	1620	14.50	2100	15.33	2080	12.83	1820	7.50	1820	7.17	1570	12.33	2110	5.67	1010	10.83	1700	12.44	1800
1933	201-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1934	101-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1935	601-10	9.33	1390	8.00	1320	8.17	1460	8.50	1340	9.33	1550	9.67	1620	8.83	1470	8.83	1370	8.33	1350	6.83	1100	8.50	1347
1936	501-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Average 25 Years		14.16	1571	13.51	1751	14.84	1653	14.54	1504	14.25	1588	14.29	1992	13.78	1821	14.36	1573	13.89	1882	13.93	1516	14.11	1558
Increase over "Av. of None"				−0.60	193	0.73	95	0.43	54			0.18	454	−0.33	263	0.25	15	−0.22	324				
Increase per cent				−4.25	12.39	5.17	6.10	3.05	3.47			1.28	29.14	−2.34	16.88	1.77	0.96	−1.56	20.80				

NOTE.—The minus (−) sign indicates decrease. Crop failures in 1933, 1934, and 1936 due to drought.
None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

OATS AND PEAS

TABLE 36.—Yields of Oats and Peas Following Certain Soil Treatments at Highmore, S. D., Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	401-10	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500	0.00	500
1913	301-10	0.50	640	0.42	595	0.92	625	0.67	730	0.75	655	0.75	805	0.58	715	0.42	1335	0.50	1070	0.42	1005	0.56	767
1914	201-10	2.25	925	1.77	1044	1.92	1175	2.10	1264	2.13	1232	1.27	1594	1.17	1700	1.82	1741	1.42	1665	2.23	1266	2.20	1141
1915	601-10		3800		5200		5000		5750		5600		5850		5850		5100		6350		5600		5000
1916	501-10		3660		4490		3920		3650		3940		6280		4430		3750		5920		3800		3800
1917	401-10		2210		2890		2540		2210		2300		4000		2000		2480		4100		2230		2247
1918	301-10		2470		2430		1300		1140		2090		2730		1900		1650		2250		1020		1860
1919	201-10		3750		3980		4380		3830		3950		4220		3950		2380		3850		3500		3733
1920	101-10		4750		6400		6150		5000		4850		5750		5850		5250		5600		4350		4650
1921	501-10		640		520		810		610		420		660		440		1060		1000		770		610
1922	401-10		3920		5100		4900		4300		4200		6300		5730		4750		6350		4600		4240
1923	301-10		3170		5050		3220		2960		3000		5130		5300		3510		3600		3250		3140
1924	201-10		3770		3250		3650		3000		2840		4750		3460		3750		5000		2770		3127
1925	101-10		2000		2000		2350		1800		1850		2700		1900		2200		3120		2250		2033
1926	601-10		0		0		0		0		0		0		0		0		0		0		0
1927	401-10		1480		2400		2100		1750		1600		2950		2470		2060		3220		1780		1620
1928	301-10		1170		910		660		670		630		1160		800		790		1280		850		883
1929	201-10		1430		2170		1750		1580		1580		2410		2010		1710		2430		1010		1340
1930	101-10		1700		2200		1630		1540		1510		2400		2060		1790		2530		1710		1640
1931	601-10		0		0		0		0		0		0		0		0		0		0		0
1932	501-10		2580		2350		2570		2530		2630		2300		2440		2660		2330		2320		2510
1933	301-10		0		0		0		0		0		0		0		0		0		0		0
1934	201-10		0		0		0		0		0		0		0		0		0		0		0
1935	101-10		1280		1630		1610		1280		1300		1720		1500		1650		2010		1470		1350
1936	601-10		0		0		0		0		0		0		0		0		0		0		0
Average Peas 3 Years		0.92	688	0.73	713	0.95	767	0.92	831	0.96	796	0.67	966	0.92	972	0.75	1192	0.64	1078	0.88	924	0.92	803
Increase over "Av. of None"				−0.19	−90	0.03	−36	0.00	28			−0.25	163	0.00	169	−0.17	389	−0.28	275				
Increase per cent				−20.65	−11.21	3.26	−4.48	0.00	3.50			−27.17	20.30	0.00	21.05	−18.48	48.44	−30.43	34.25				
Average Peas and Oats 22 Years			1990		2408		2206		1982		2013		2787		2368		2115		2770		1967		1990
Increase over "Av. of None"					418		216		−8				797		378		125		780				
Increase per cent					21.01		10.85		−0.40				40.05		18.99		6.28		39.20				

NOTE.—The minus (−) sign indicates decrease. Crop failure in 1926, 1931, 1933, 1934, and 1936 due to drought.
None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

SORGHUM

TABLE 37.—Yields of Sorghum Following Certain Soil Treatments at Highmore, S. D., Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	501-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1913	401-10	9.82	660	11.70	835	10.62	880	12.14	985	16.79	1250	15.36	1105	17.14	1315	13.57	980	10.98	780	9.82	670	12.14	860
1914	301-10	9.48	1009	12.29	1252	14.21	1314	12.84	1251	12.25	1194	14.60	1372	10.07	996	10.54	1160	10.87	1101	9.93	1074	10.55	1092
1915	201-10	0.00	1410	0.27	1950	0.98	2210	0.80	2130	0.00	1790	0.98	2160	0.27	1810	2.77	2080	2.32	2290	0.09	1950	0.03	1717
1916	601-10	3.04	1450	4.11	1170	4.29	1290	1.07	600	2.32	800	2.50	470	1.07	350	3.40	760	3.04	500	1.43	410	2.26	887
1917	501-10	12.95	1650	14.29	2000	16.43	1600	11.25	1400	11.07	1450	12.68	1400	12.32	1800	12.14	1600	8.57	1000	9.46	1350	11.16	1483
1918	401-10	21.43	2400	22.14	1760	17.68	2010	20.54	2300	30.00	2770	26.96	2490	25.71	2510	23.57	2330	20.36	1860	18.57	2110	23.33	2427
1919	301-10	20.18	2530	18.21	2460	18.39	2820	18.57	2580	21.07	2890	20.00	2590	18.04	2790	15.54	2530	19.29	2670	23.75	2980	21.67	2800
1920	201-10	27.14	4060	33.93	4080	39.29	3810	32.22	4330	33.39	4420	45.18	3790	36.43	3580	42.68	4280	46.61	4240	35.18	4310	31.90	4263
1921	101-10	28.21	3120	29.11	3270	20.89	4460	20.18	4270	22.86	3950	18.21	3680	22.50	3560	17.86	4770	20.54	3520	24.29	3980	25.12	3683
1922	501-10	27.77	2535	33.21	3040	27.32	2420	21.43	2210	23.57	2130	30.36	2620	31.43	3690	35.18	3440	32.14	3770	28.21	3040	26.52	2568
1923	401-10	28.57	5200	23.39	4340	26.61	3660	24.82	4610	25.00	4350	18.39	3970	19.29	4220	20.89	4530	20.71	5040	23.39	4840	25.65	4797
1924	301-10	10.71	2800	14.29	2550	15.36	2960	9.82	2700	11.61	2600	17.14	3240	11.61	2770	10.18	2780	14.11	2860	10.71	3000	11.01	2800
1925	201-10	10.98	1595	6.43	1070	5.98	1525	7.77	1545	8.84	1485	5.89	1140	4.46	1030	5.09	1945	4.55	1355	8.04	1550	9.29	1543
1926	101-10	0.00	1650	0.00	1250	0.00	1650	0.00	1460	0.00	1400	0.00	1070	0.00	1050	0.00	1570	0.00	1460	0.00	1650	0.00	1567
1927	601-10	21.43	1920	27.50	2360	25.18	2290	22.86	2300	25.18	2540	35.18	3020	26.79	2610	30.89	2770	34.29	3030	23.93	2200	23.51	2220
1928	401-10	2.23	1475	0.98	1115	0.54	970	0.71	860	1.43	1610	1.16	1085	1.70	1285	0.80	1415	0.54	1070	0.71	1160	1.46	1415
1929	301-10	4.11	970	5.71	830	5.71	980	5.18	1210	4.46	1000	4.46	850	2.50	960	0.54	670	1.96	1140	0.98	545	3.18	838
1930	201-10	20.89	2230	22.77	2075	21.96	1890	19.46	2260	21.70	2205	23.30	2115	23.75	1970	21.79	2130	23.21	2790	19.91	2335	20.83	2257
1931	101-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1932	601-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1933	501-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1934	301-10	0.00	950	0.00	600	0.00	850	0.00	900	0.00	1000	0.00	500	0.00	550	0.00	750	0.00	1000	0.00	950	0.00	967
1935	201-10	7.32	1490	8.21	1490	8.57	1470	8.21	1640	9.11	1690	9.82	1500	7.32	1340	9.11	1440	8.93	1550	7.32	1440	7.92	1540
1936	101-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Average 25 Years		10.65	1644	11.54	1580	11.20	1642	9.99	1662	11.23	1701	12.09	1607	10.90	1607	11.06	1757	11.32	1721	10.23	1662	10.70	1669
Increase over "Av. of None"				0.84	−89	0.50	−27	−0.71	−7			1.39	−62	0.20	−62	0.36	88	0.62	52				
Increase per cent				7.85	−5.33	4.67	−1.62	−6.64	−0.42			12.99	−3.71	1.87	−3.71	3.36	5.27	5.79	3.12				

NOTE.—The minus (−) sign indicates decrease. Total crop failure in 1912, 1931, 1932, 1933, and 1936 due to drought.
None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

OATS

TABLE 38.—Yields of Oats Following Certain Soil Treatments at Highmore, S. D. Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Year	Acre	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1912	601-10	0.00	610	0.00	520	0.00	810	0.00	830	0.00	1120	0.00	1300	0.00	1250	0.00	900	0.00	550	0.00	530	0.00	753
1913	501-10	0.63	1110	0.78	825	0.47	705	0.63	560	3.13	1040	1.25	760	2.81	880	3.13	960	1.56	980	2.19	860	1.98	1003
1914	401-10	44.06	2320	30.94	2040	28.13	1830	32.19	1810	38.75	1920	41.56	1850	41.25	1960	35.94	1880	36.88	1950	36.25	2000	39.69	2080
1915	301-10	99.06	3130	105.93	3510	98.44	3250	92.19	2950	93.75	2650	112.50	3900	106.25	3600	108.44	3630	85.00	2830	106.25	3600	99.69	3127
1916	201-10	71.86	2500	65.00	2850	68.75	3000	69.38	2480	71.25	2420	60.00	3630	65.00	3120	74.38	2970	63.75	3590	75.00	2600	72.70	2507
1917	601-10	35.63	1210	35.31	1120	47.81	1340	34.38	1160	35.94	1280	39.69	1330	31.88	1000	41.56	1360	42.19	1250	36.56	1010	36.04	1167
1918	501-10	36.56	860	48.75	1290	47.19	1190	36.88	990	40.63	1230	40.31	1430	42.19	1320	55.00	1290	55.00	1810	42.19	1350	39.79	1147
1919	401-10	37.50	1210	35.63	1190	43.13	1590	43.44	1460	42.81	1090	44.69	1020	51.88	870	50.63	890	45.63	1120	51.88	720	44.06	1007
1920	301-10	57.19	1520	82.50	2190	51.88	1450	50.63	1350	54.06	1540	75.94	2290	79.06	2350	66.25	1880	71.88	2500	68.75	2100	60.00	1720
1921	201-10	17.50	640	15.94	700	19.06	690	16.88	560	18.75	640	19.06	930	18.44	710	20.31	780	18.44	1060	16.56	600	17.60	627
1922	101-10	55.94	1730	65.31	2210	75.31	2030	66.56	1950	64.69	1820	76.25	2410	67.81	2110	75.63	2100	81.56	2540	71.88	2070	64.17	1873
1923	501-10	63.13	2150	64.06	2120	67.81	1710	62.50	1660	63.44	2020	64.06	2650	55.94	2610	49.38	1520	66.25	3050	55.31	2090	60.63	2087
1924	401-10	35.94	850	68.75	1970	44.06	1150	32.81	750	33.13	760	78.75	2380	70.63	2020	32.19	920	80.31	2490	42.19	950	37.09	853
1925	301-10	36.25	1190	40.94	1740	37.03	1165	33.75	1020	41.88	1280	48.75	2290	39.84	1725	40.31	1360	43.44	2060	39.69	1330	39.27	1267
1926	201-10	4.06	390	3.13	300	2.27	228	3.59	435	2.73	413	1.95	458	1.56	400	0.47	305	0.63	450	1.17	143	2.65	315
1927	101-10	42.34	1075	51.88	1620	51.56	1190	44.84	1075	45.16	1065	52.66	1795	48.91	1355	50.31	1240	58.75	2000	47.66	1195	45.05	1112
1928	601-10	15.16	1335	17.03	1055	24.38	1120	24.06	1030	25.31	990	23.13	1110	22.50	1280	20.31	950	13.44	1320	14.69	1030	18.39	1118
1929	401-10	31.25	920	29.69	1160	22.19	990	27.19	850	31.25	1000	24.06	1330	30.31	1290	27.19	800	19.84	1265	18.44	730	26.98	883
1930	301-10	28.44	750	41.88	1210	31.56	740	28.13	600	26.56	510	48.13	1560	41.25	1400	38.13	1050	48.13	1660	36.88	940	30.63	733
1931	201-10	2.13	382	5.84	463	5.53	423	8.31	484	7.63	506	6.59	669	6.44	414	8.88	566	8.69	722	6.41	455	5.39	448
1932	101-10	45.00	1910	37.19	2110	35.00	1780	31.88	1780	31.25	1550	26.25	1560	29.06	1470	25.63	2080	23.13	1760	31.25	1800	35.83	1753
1933	601-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1934	501-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
1935	301-10	18.44	740	20.94	790	19.69	750	17.81	630	16.25	700	17.50	970	20.31	910	20.94	880	22.19	1090	20.00	960	18.23	800
1936	201-10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Average 25 Years		31.12	1141	34.70	1319	32.85	1165	30.32	1057	31.53	1102	36.16	1505	34.93	1362	34.80	1212	35.47	1522	32.85	1163	31.83	1135
Increase over "Av. of None"				2.87	184	1.02	30	−1.51	−78			4.33	370	3.10	227	2.97	77	3.64	387				
Increase per cent				9.02	16.21	3.20	2.64	−4.74	−6.87			13.60	32.60	9.74	20.00	9.33	6.78	11.44	34.10				

NOTE.—The minus (−) sign indicates decrease. Total crop failure in 1933, 1934, and 1936 due to drought.
None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

ALFALFA

TABLE 39.—Yields of Alfalfa Seed and Straw Following Certain Soil Treatments at Highmore, S. Dak., Rotation No. 1

Treatment		None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
Plot No.		−1		−2		−3		−4		−5		−6		−7		−8		−9		−10			
Yield		Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Year	Acre	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1922	601-10	40	890	15	565	25	905	30	770	45	965	25	935	30	900	20	760	15	685	15	665	33	840
1923	601-10	48	2253	60	2140	58	2693	50	2450	53	3918	35	2715	48	2453	45	2505	63	2438	75	2465	59	2879
1924	501-10	43	1395	105	1595	58	1443	98	1413	118	1583	130	1820	140	1590	98	1553	118	1733	75	1475	79	1484
Average 24 Years		5.5	189	7.5	178	5.9	210	7.4	193	9.0	269	7.9	228	9.1	206	6.8	201	8.2	202	6.9	192	7.1	217
Increase over "Av. of None"				0.4	−39	−1.2	−7	0.3	−24			0.8	11	2.0	−11	−0.3	−16	1.1	−15				
Increase per cent				5.63	−17.97	16.90	−3.22	4.23	−11.06			11.27	5.07	28.17	−5.07	−4.23	−7.37	15.50	−6.91				

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

TABLE 40.—Yields of Alfalfa Hay Following Certain Soil Treatments at Highmore, S. D.
Rotation No. 1

Treatment	None	N	P	K	None	NP	NK	PK	NPK	None	Average of None
Plots No.	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	
Yield	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.	Lbs. Lbs.
Year Cut Acre	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total	Cut Total
1912 101-10	Seeded May 22. No record of any yield.										
1913 1 101-10	1400 1400	1600 1600	1550 1550	1220 1220	1120 1120	2400 2400	1800 1800	1500 1500	2700 2700	1800 1800	1440 1440
1914 1 101-10	1630	1730	1880	1310	1040	1770	1880	1250	1570	1480	1383
1914 2 101-10	970 2600	1470 3200	770 2650	630 1940	580 1620	1610 3380	2670 4550	730 1980	2250 3820	1090 2570	880 2263
1915 1 101-10	2020	2160	2330	2100	1800	2460	1710	1860	1860	1970	1930
1915 2 101-10	2200	2200	2360	2050	1810	2440	1970	2110	2230	1950	1987
1915 3 101-10	2960 7180	3250 7610	3040 7730	2750 6900	2480 6090	3210 8110	3170 6850	3070 7040	3520 7610	3070 6990	2837 6753
1916 1 101-10	2750	2620	3030	2220	1950	3450	2510	3220	3000	2950	2550
1916 2 101-10	1910 4660	2080 4700	2120 5150	1960 4180	1890 3840	2410 5860	2290 4800	2550 5770	2520 5520	2680 5630	2160 4710
1917 1 101-10	800	2520	3100	2260	1900	3220	2920	2820	2480	2400	1700
1917 2 101-10	1360 2160	1000 3520	770 3870	750 3010	670 2570	670 3890	1020 3940	770 3590	1000 3480	990 3390	1007 2707
1918 601-10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
1919 1 601-10	2450	1950	3050	2600	3450	3250	2880	2950	2300	2400	2767
1919 2 601-10	1350 3800	1450 3400	1280 4330	1300 3900	1550 5000	1600 4850	1550 4430	1100 4050	1480 3780	1050 3450	1317 4083
1920 1 601-10	2110	2220	2580	2470	2570	3020	2520	2470	2560	1920	2200
1920 2 601-10	2750	2930	3010	3020	3120	3220	3100	3140	3150	2720	2863
1920 3 601-10	2350 7210	2480 7630	2650 8240	2540 8030	2870 8560	2910 9150	2710 8330	2300 7910	2680 8390	2460 7100	2560 7627
1921 1 601-10	3210	2260	3260	3950	4330	4570	4070	3630	4140	3700	3747
1921 2 601-10	860 4070	670 2930	860 4120	1000 4950	1700 6030	1500 6070	1030 5100	660 4290	750 4890	780 4480	1113 4860
1922 1 601-10	2960	2280	2830	2600	2970	3000	2640	2680	2720	2500	2810
1922 2 601-10	1130 4090	950 3230	1200 4030	1300 3900	1430 4400	1550 4550	1360 4000	1300 3980	1150 3870	1020 3520	1193 4003
1923 1 601-10	990 990	990 990	1130 1130	960 960	970 970	1130 1130	1000 1000	990 990	1080 1080	1040 1040	1000 1000
1924 1 501-10	2010 2010	1770 1770	2590 2590	1680 1680	2060 2060	2010 2010	1400 1400	2200 2200	1910 1910	1400 1400	1823 1823
1925 1 501-10	2800 2800	2270 2270	2610 2610	2400 2400	2600 2600	2580 2580	2200 2200	2600 2600	2500 2500	2230 2230	2543 2543
1926 501-10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
1927 1 501-10	3590	2960	3450	2990	3170	3520	2620	3300	3450	2730	3163
1927 2 501-10	1070 4660	930 3890	850 4300	700 3690	730 3900	920 4440	920 3540	930 4230	750 4200	750 3480	850 4013
1928 1 501-10	1040 1040	780 780	1020 1020	910 910	1090 1090	1120 1120	780 780	920 920	870 870	830 830	987 987
1929 1 501-10	2260 2260	1820 1820	2320 2320	1860 1860	2100 2100	2270 2270	2070 2070	2340 2340	2430 2430	2130 2130	2163 2163
1930 1 401-10	1120	1200	630	630	950	450	650	350	330	330	800
1930 2 401-10	830 1950	780 1980	400 1030	490 1120	620 1570	1440 1890	1220 1870	450 800	2310 2640	450 780	633 1433
1931 401-10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
1932 1 401-10	800 800	800 800	250 250	550 550	920 920	1400 1400	1150 1150	700 700	1500 1500	750 750	823 823
1933 1 401-10	750 750	450 450	240 240	430 430	630 630	310 310	570 570	200 200	220 220	480 480	620 620
1934 401-10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
1935 1 401-10	920 920	910 910	900 900	880 880	830 830	980 980	930 930	1190 1190	1090 1090	1030 1030	927 927
1936 301-10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
AVERAGE 1st	1484	1387	1615	1418	1519	1788	1513	1549	1613	1420	1474
AVERAGE 2nd	601	603	568	550	588	723	714	573	733	562	583
AVERAGE 3rd	221	239	237	220	223	255	245	224	258	230	225
AVERAGE TOTAL 24 Yrs.	2306	2228	2419	2188	2329	2766	2471	2345	2604	2212	2282
Increase over "Av. of None"		−54	137	−94		484	189	63	322		
Increase per cent		−2.37	6.00	−4.12		21.21	8.28	2.76	14.11		

NOTE.—The minus sign (−) indicates decrease. None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
In 1912 alfalfa was seeded and there was, of course, no crop to cut that year.
Second cuttings were made 10 years out of a possible 24. Third cuttings were possible for only two years.
The averages for all cuttings and the total for each year are for 24 years.

SUMMARY

TABLE 41.—Summary of the Results From All Treatments on All Crops—Corn, Wheat, Peas, Peas and Oats, Sorghum, Oats, and Alfalfa in Rotation 1, Highmore, S. Dak., 1912 to 1936, Expressed as Weighted Averages

Crop	Corn	Grain	Corn Stalks		Wheat Grain		Wheat Straw		Peas	Grain	Peas Straw		Peas & Oats Hay	
No of Yrs.	25		24		25		25		3		3		22	
Treatment	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.
None	15.63		1297		14.11		1558		0.92		803		1990	
N	14.57	−1.06	1323	26	13.51	−0.60	1751	193	0.73	−0.19	713	−90	2408	418
P	14.93	−0.70	1393	96	14.84	**0.73**	1653	95	0.95	**0.03**	767	−36	2206	216
K	14.55	−1.08	1356	59	14.54	0.43	1504	54	0.92	0.00	831	28	1982	−8
NP	15.42	**−0.21**	1413	116	14.29	0.18	1992	454	0.67	−0.25	966	163	2787	**797**
NK	14.43	−1.20	1420	**123**	13.78	−0.33	1821	263	0.92	0.00	972	169	2368	378
PK	14.74	−0.89	1373	76	14.36	0.25	1573	15	0.75	−0.17	1192	**389**	2115	125
NPK	14.44	−1.19	1338	41	13.89	−0.22	1882	324	0.64	−0.28	1078	275	2770.	780

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
N	−6.78	2.00	−4.25	12.39	−20.65	−11.21	21.01
P	−4.48	7.40	**5.17**	6.10	**3.26**	−4.48	10.85
K	−6.91	4.55	3.05	3.47	0.00	3.50	−0.40
NP	**−1.34**	8.94	1.28	**29.14**	−27.17	20.30	**40.05**
NK	−7.68	**9.48**	−2.34	16.88	0.00	21.05	18.99
PK	−5.69	5.86	1.77	0.96	−18.48	**48.44**	6.28
NPK	−7.61	3.16	−1.56	20.80	−30.43	34.25	39.20

NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment. The figures indicating the greatest increase in yield in each crop are printed in bold face type.

TABLE 41.—(Continued)

No. of Yrs.	Sorghum	Grain	Sorghum	Stalks	Oats	Grain	Oats	Straw	Alfalfa Seed		Alfalfa Straw		Alfalfa Hay	
	25		25		25		25		24		24		24	
Treatment	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Bu.	Gain Bu.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.	Yield Lbs.	Gain Lbs.
None	10.70		1669		31.83		1135		7.1		217		2282	
N	11.54	0.84	1580	−89	34.70	2.87	1319	184	7.5	0.4	178	−39	2223	−54
P	11.20	0.50	1642	−27	32.85	1.02	1165	30	5.9	−1.2	210	−7	2419	137
K	9.99	−0.71	1662	−7	30.32	−1.51	1057	−78	7.4	0.3	193	−24	2188	−94
NP	12.09	**1.39**	1607	−62	36.16	**4.33**	1505	370	7.9	0.8	228	**11**	2766	484
NK	10.90	0.20	1607	−62	34.93	3.10	1362	227	9.1	**2.0**	206	−11	2471	189
PK	11.06	0.36	1757	88	34.80	2.97	1212	77	6.8	0.3	201	−16	2345	63
NPK	11.32	0.62	1721	52	35.47	3.64	1522	387	8.2	1.1	202	−15	2604	322

Percentage Increase or Decrease for the Several Treatments for the Several Crops Over No Treatment

Treatment	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
N	7.85	−5.33	9.02	16.21	5.63	−17.97	−2.37
P	4.67	−1.62	3.20	2.64	−16.90	−3.22	6.00
K	−6.64	−0.42	−4.74	−6.87	4.23	−11.06	−4.12
NP	**12.99**	−3.71	**13.60**	32.60	11.27	**5.07**	**21.21**
NK	1.87	−3.71	9.74	20.00	**28.17**	−5.07	8.28
PK	3.36	**5.27**	9.33	6.78	−4.23	−7.37	2.76
NPK	5.79	3.12	11.44	**34.10**	15.50	−6.91	14.11

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.
NOTE.—The minus (−) sign indicates decrease in yield as compared with yield following no treatment. The figures indicating the greatest increase in yield in each crop are printed in bold face type.

GENERAL SUMMARY

TABLE 42.—General Summary of the Results From All Treatments on All Crops: Corn, Wheat, Peas, Peas and Oats, Sorghum, Oats, and Alfalfa in Rotation 1, Highmore, S. D., 1912 to 1936, Expressed in Terms of the Total Amounts of Dry Matter Produced per Acre

Treatment / Crop	No. Yrs.	None Grain Lbs.	N Grain Lbs.	P Grain Lbs.	K Grain Lbs.	NP Grain Lbs.	NK Grain Lbs.	PK Grain Lbs.	NPK Grain Lbs.
Corn	25	27,353	25,498	26,128	25,463	26,985	25,253	25,795	25,270
Wheat	25	21,165	20,265	22,260	21,810	21,435	20,670	21,540	20,835
Peas	3	166	131	170	166	121	165	134	115
Sorghum	25	14,982	16,158	15,681	13,993	16,922	15,254	15,486	15,849
Oats	25	25,466	27,757	26,280	24,257	28,931	27,946	27,040	28,374
Alfalfa Seed	24	171	180	141	178	190	218	163	196
Total	(127)	89,303	89,989	90,660	85,867	94,584	89,506	90,158	90,639
Total Gain		------	686	1,357	−3,436	5,281	203	855	1,336
Av. Gain per Yr.		------	5.40	10.69	−27.06	41.58	1.60	6.73	10.52
Gain per cent		------	0.77	1.52	−3.85	5.91	0.23	0.96	1.50

		Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay	Straw, Stalks, and Hay
Corn	24	31,128	31,752	33,432	32,544	33,912	34,080	32,952	32,112
Wheat	25	38,950	43,775	41,325	37,600	49,800	45,525	39,325	47,050
Peas	3	2,408	2,139	2,300	2,494	2,899	2,915	3,576	3,235
Peas and Oats Hay	22	43,783	52,970	48,540	43,600	61,310	52,090	46,540	60,940
Sorghum	25	41,724	39,497	41,059	41,541	40,167	40,186	43,930	43,026
Oats	25	28,380	32,983	29,131	26,414	37,622	34,044	30,311	38,047
Alfalfa Straw	24	5,203	4,300	5,041	4,633	5,470	4,943	4,818	4,856
Alfalfa Hay	24	54,778	53,480	58,060	52,510	66,390	59,310	56,280	62,500
Total	(148)	246,354	260,896	258,888	241,336	297,570	273,093	257,732	291,766
Total Gain		------	14,542	12,534	−5,018	51,216	26,739	11,378	45,412
Av. Gain per Yr.		------	98.26	84.69	−33.91	346.05	180.67	76.88	306.84
Gain per cent		------	5.90	5.09	−2.04	20.78	10.85	4.62	18.43

Total Amount of Dry Matter Produced Under the Several Treatments

	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay	Grain, Straw, Stalks, and Hay
Corn	58,481	57,250	59,560	58,007	60,897	59,333	58,747	57,382
Wheat	60,115	64,040	63,585	59,410	71,235	66,195	60,865	67,885
Peas	2,574	2,270	2,470	2,660	3,020	3,080	3,710	3,350
Peas and Oats Hay	43,783	52,970	48,540	43,600	61,310	52,090	46,540	60,940
Sorghum	56,706	55,655	56,740	55,534	57,089	55,440	59,416	58,875
Oats	53,846	60,740	55,411	50,671	66,553	61,990	57,351	66,421
Alfalfa	60,152	57,960	63,242	57,321	72,050	64,471	61,261	67,552
Total	335,657	350,885	349,548	327,203	392,154	362,599	347,890	382,405
Total Gain	------	15,228	13,891	−8,454	56,497	26,942	12,233	46,748
Av. Gain per Yr.	------	103.66	95.38	−60.97	387.63	182.27	83.61	317.36
Gain per cent	------	4.54	4.14	−2.52	16.83	8.03	3.64	13.93

General Summary of the Increases in Yield for the Several Treatments Over No Treatment for All Crops Grown

Total Gain Grain	686	1,357	−3,436	5,281	203	855	1,336
Total Gain Straw, Etc.	14,542	12,534	−5,018	51,216	26,739	11,378	45,412
Total Gain Dry Matter	15,228	13,891	−8,454	56,497	26,942	12,233	46,748
Gain per cent Grain	0.77	1.52	−3.85	5.91	0.23	0.96	1.50
Gain per cent Straw, Etc.	5.90	5.09	−2.04	20.78	10.85	4.62	18.43
Gain per cent Total Dry Matter	4.54	4.14	−2.52	16.83	8.03	3.64	13.93

None—no treatment. N—nitrogen. P—phosphorus. K—potassium.

NOTE.—The minus (−) sign indicates decrease.
The average yields per acre per year for None (No Treatment) for all crops were: Grain, 703 lbs.; straw, etc., 1665; total, 2368 lbs.