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The Results of Twenty Years Complete Soil Fertility Tests Brookings, S. D.

J.G. Hutton

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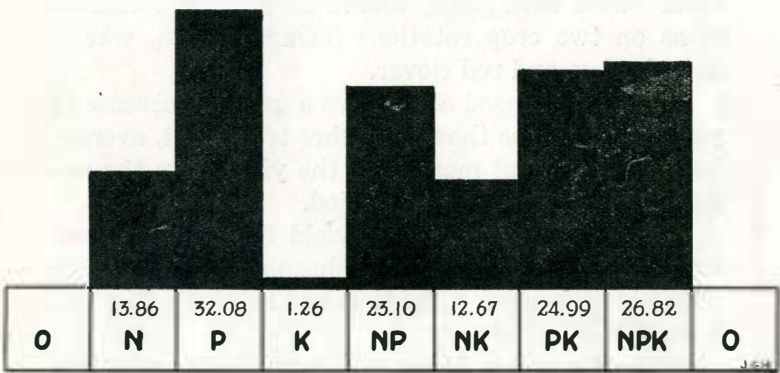
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The Results of Twenty Years Complete Soil Fertility Tests Brookings, S. D.

Joseph Gladden Hutton



Agronomy Department
Agricultural Experiment Station
South Dakota State College of
Agriculture and Mechanic Arts
Brookings

SUMMARY

This bulletin reports the results obtained from twenty years fertility investigations on Barnes sandy loam soil at Brookings, S. D.

The three elements of plant food commonly applied in fertilizers—nitrogen, phosphorus, and potassium—were used singly and in all possible combinations on two crop rotations including corn, wheat, oats, barley, and red clover.

Phosphorus used alone gave a greater increase in yield for all crops than any other treatment, averaging 32.08 per cent more than the yield from the untreated soil for the entire period.

The average increase in yield for all crops, following the application of phosphorus, was 1979 pounds per acre per year. In round numbers, to make it easy to remember:

Phosphorus has increased the yield of crops one ton per acre per year for twenty years.

Results of Twenty Years Complete Soil Fertility Tests at Brookings, S. D.

Joseph Gladden Hutton

Associate Agronomist in Charge of Soil Investigations

Introduction

The data reported in this bulletin 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 Professor 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 as a member of the agronomy department.

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 orig-

inal supply in the soil against the loss due to the removal of definite quantities of the several elements in the crops grown.

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 6, it has been thought best to retain the original varieties in the test, 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.

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, "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

O	N	P	K	O	NP	NK	PK	NPK	O
140	141	142	143	144	145	146	147	148	149

ROTATION NO. 25.

CORN-OATS-WHEAT-BARLEY-RED CLOVER.

O	N	P	K	O	NP	NK	PK	NPK	O
150	151	152	153	154	155	156	157	158	159

ROTATION NO. 27.

CORN-WHEAT-BARLEY-OATS-RED CLOVER.

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.

the region of dark colored, calcium carbonate accumulating soils the removal of soluble material 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 twenty plots as follows:

Total Nitrogen, 0.31677% or 6,335 lb in 2,000,000 lb of soil;

Total Phosphorus, 0.06655% or 1,330 lb in 2,000,000 lb of soil;

Total Potassium 1.37925% 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% 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, 1908-1914, 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 and before harrowing the fall-plowed land in preparation for seeding.

Crops Grown

The crops employed in the two rotations are:

Corn: Brookings S. D. No. 86
Wheat: Acme S. D. No. 284
Barley: Odessa S. D. No. 182
Oats: Sixty Day S. D. No. 165
Clover: Medium Red S. D. grown.

Harvesting Crops

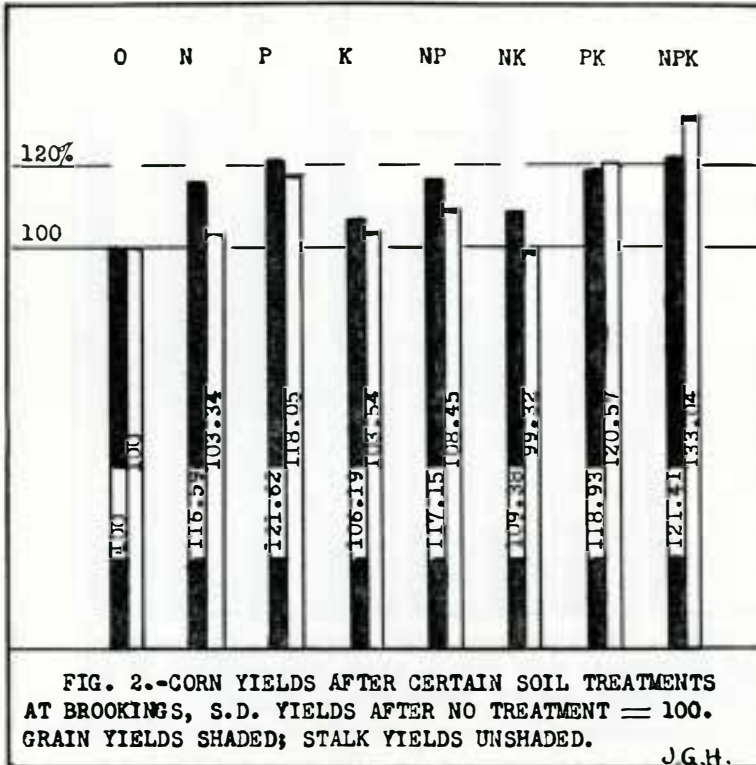
The crops from the several plots have been harvested separately, threshed separately, the grain and straw carefully weighed, and the weights recorded. However, the corn stalks were not weighed in 1910; at least there is no record of such weights. The corn has been harvested from the standing stalks and 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.

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 of the years grown are recorded.

Corn.—Table No. 1 shows that the average yield of corn for the four years when this crop was grown was, for the untreated plots, 34.23 bushels per acre. The average yield of stalks for the three years when stalks were weighed was 1468 pounds per acre. See page 16.

The greatest average increase in yield for any treatment over the yield of the untreated plots was 7.40 bushels of grain, or 21.62%, for phosphorus alone, and 485 pounds of stalks, or 33.04%, 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.

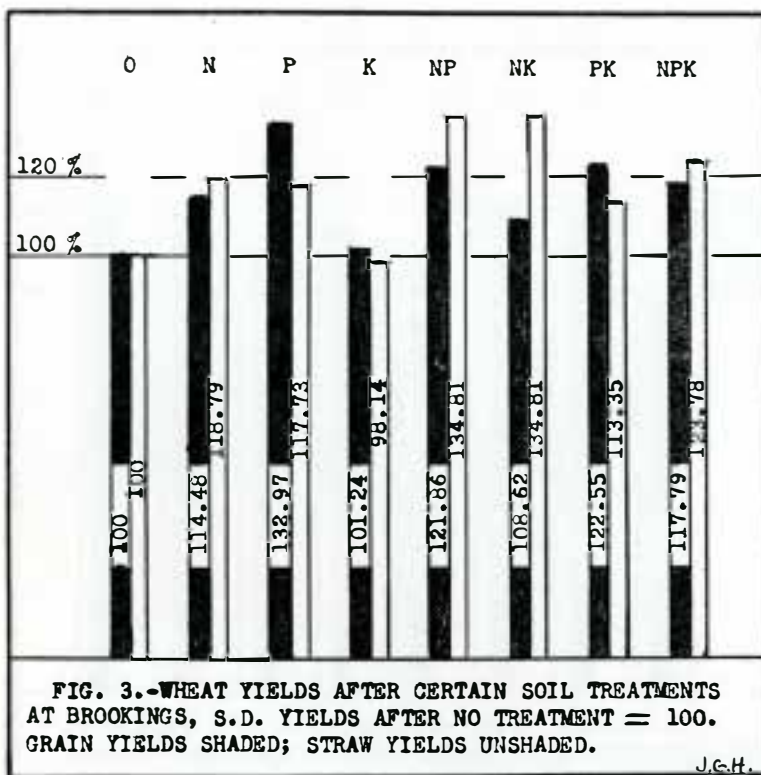


The comparative yields of grain and stalks, in per cent, are shown graphically in Figure 2.

Wheat.—Table No. 2 shows the yields of wheat for nine years. The average yield of grain for the untreated plots is 14.50 bushels per acre and of straw 1985 pounds per acre. See page 16.

The greatest increase in the average yield of grain follows the application of phosphorus, 4.78 bushels per acre, or 32.97%, while the greatest average increase in straw is 691 pounds per acre, or 34.81%, for the same treatment.

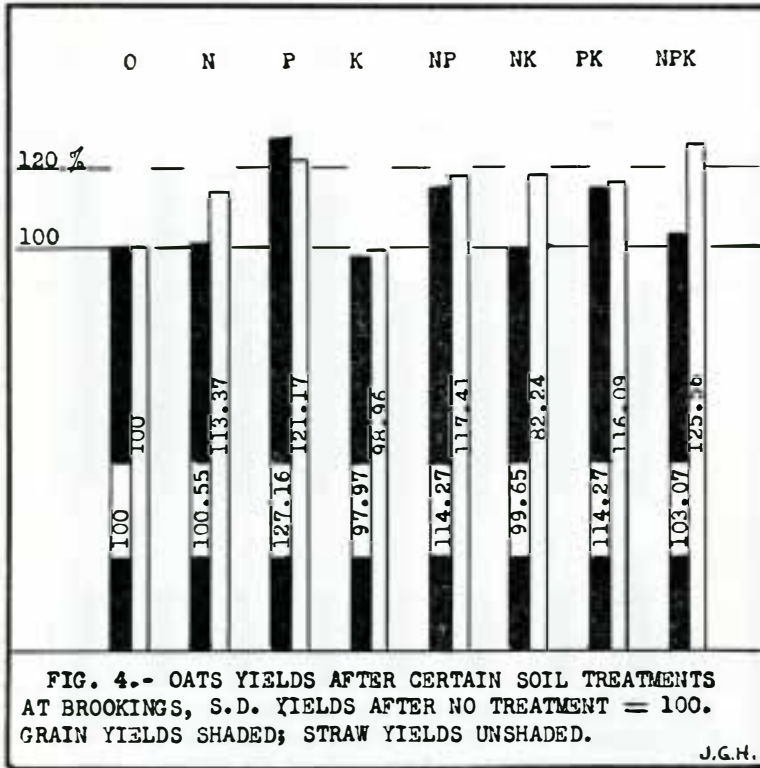
The comparative yields of grain and straw, in per cent, for the several treatments are shown graphically in Figure 3 .



Oats.—Table No. 3 shows the average yields of oats following the several treatments. The average yield of oats for eight years was, for the untreated plots, 34.54 bushels of grain and 1436 pounds of straw per acre. The largest increase in average yield of grain, 9.38 bushels per acre, or 27.16%, follows the application of phosphorus, while the greatest average increase in straw, 367 pounds per acre, or 25.56%, follows the application of nitrogen, phosphorus, and potassium. See page 17.

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

Barley.—Table No. 4 shows the yields of barley for nine years. The average yield of grain on the untreated plots was 29.38 bushels and the average yield of straw was 1524 pounds per acre. The greatest increase in average yield of grain, 9.73 bushels per acre, or 33.12%, follows the application of phosphorus, while the greatest increase in yield of straw,

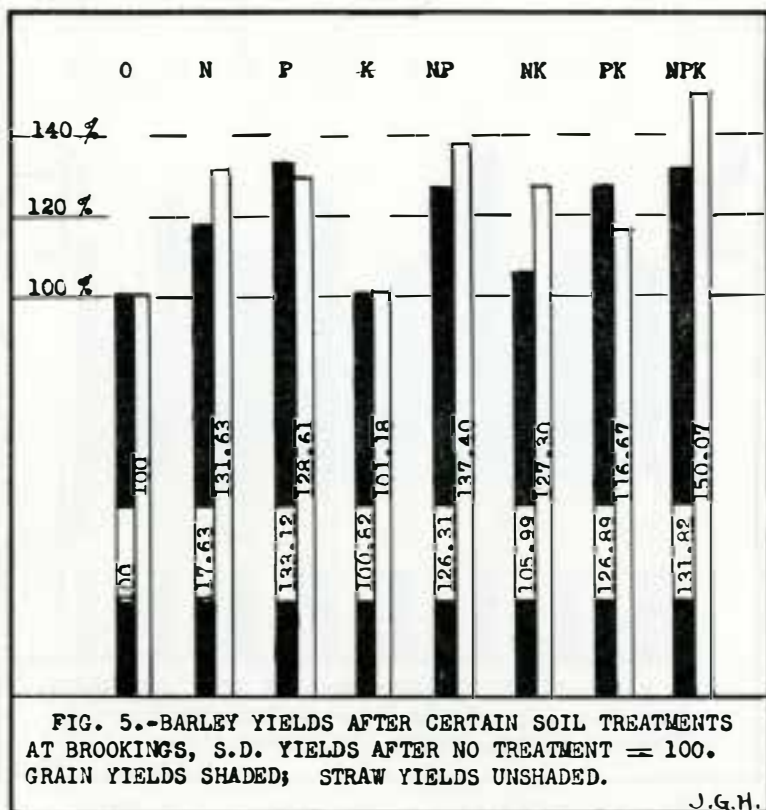


763 pounds per acre, or 50.07%, follows the application of nitrogen, phosphorus, and potassium. See page 17.

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

Red Clover.—Table No. 5 shows the average yields of red clover seed, straw, and hay for the three years that clover was 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 page 18.

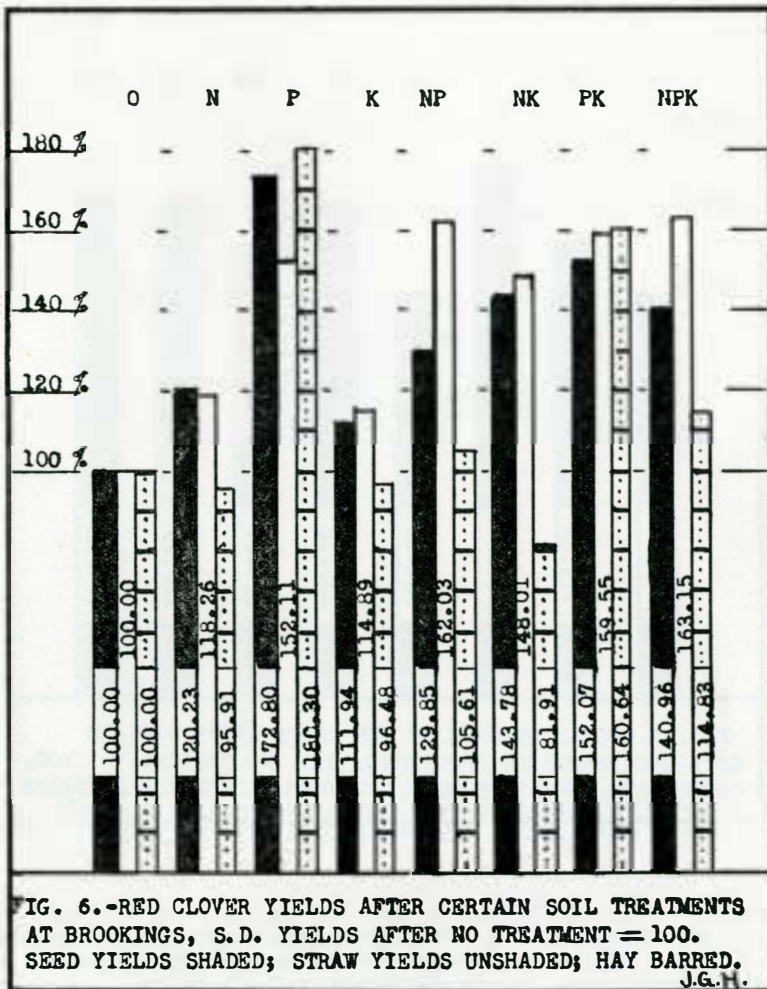
The average yield of red clover seed per acre for the three years, including the year when the yield was zero, was, for the untreated plots, 60.3 pounds while the average weight of the straw was 806 pounds per acre. The greatest average increase per acre, 43.9 pounds, or 72.80%, follows the application of phosphorus, and the greatest increase in weight of straw, 509 pounds or 63.15%, follows the application of nitrogen, phosphorus, and potassium.



The average yield of hay per acre for all cuttings for the three years, from the untreated plots, was 2299 pounds. The greatest average increase in yield of hay per acre, 1846 pounds, or 80.30%, 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.

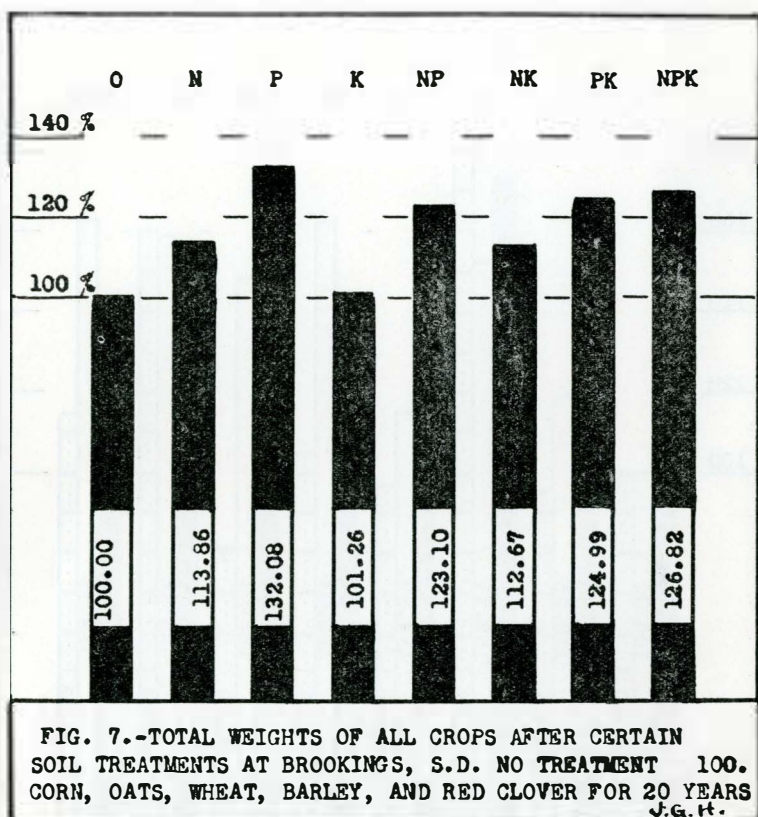
The comparative yields of clover seed, straw, and hay, in per cent, for the several treatments are shown graphically in Figure 6.

Recapitulation.—Table No. 6 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 1927. 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 19.

Summary of Yields.—Table No. 7 is a record of the total weights on the acre basis of all crops grown on plots 140-149 and 150-159 for the twenty years 1908-1927 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 twenty years and the average per year are also recorded. The percentage increases in yield for the several treatments over the yields from the untreated plots on the basis of total weights are likewise 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 twenty years but straw, stalks, and hay have been recorded for only nineteen 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, 27.80%, follows the application of phosphorus alone, and that the greatest increase in straw, stalks, and hay, combined, 35.05%, follows the same treatment. See page 20.

This table also shows that the greatest increase of total crop produced, 32.08%, follows the application of phosphorus alone. By adding the average annual increase in yield of grain due to phosphorus, namely, 679 pounds, to the weight of the average annual increase in yield of straw, stalks, and hay due to phosphorus, namely, 1300 pounds, it is found that on the plots receiving phosphorus alone the total average increase in the weight of crop per year has been 1979 pounds, practically one ton.

Figure 7 shows graphically the percentage increases in the total weight of crops for the several treatments for twenty years.

Rainfall

Figure No. 8 shows the annual rainfall at Brookings, South Dakota, from 1889 to 1932, a period of 44 years. The rainfall for the period covered in this report, 1908-1927, may be noted and the record of this period compared with the record of the preceding and succeeding years. The average annual rainfall, including melted snow, is 20.124 inches, while the total for the 44 years is 73 ft. 9½ inches. A study of these data will reveal many interesting facts which need not be repeated in this discussion.

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 twenty years, 1908-1927, the land receiving phosphorus has, with the same rainfall, produced approximately one ton more crop per acre 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 the extent of 1979 pounds per acre per year below what it has been on soil receiving sufficient phosphorus.

Cost

The cost of the phosphorus applied has been approximately \$2.20 per acre per year, although there has been some variation in the cost of phosphate. When the ton of crop produced by the application of phosphorus has a minimum value of approximately \$2.20, the application of phosphorus should be profitable. In fact, phosphorus MUST be applied to the soil because the native supply, limited as it is in respect to the needs of crops, is being depleted. This means smaller and smaller yields from the soil receiving no phosphorus and a corresponding increase in the cost of production of the small and unprofitable yields.

The judicious use of phosphorus will go far to maintain the fertility of the soil and greatly reduce the cost of production. During the twenty years, 1908-1927, three acres of land receiving phosphorus would have produced almost as much as four acres of land receiving no phosphorus. The land receiving phosphorus now has in it more of this element than when the trials began, whereas the untreated land has less.

There is nothing to indicate that there is any profit in the application of nitrogen and potassium to the soil under investigation. On the other hand, these elements have been applied at a positive loss either when applied singly or in combination with each other or with phosphorus.

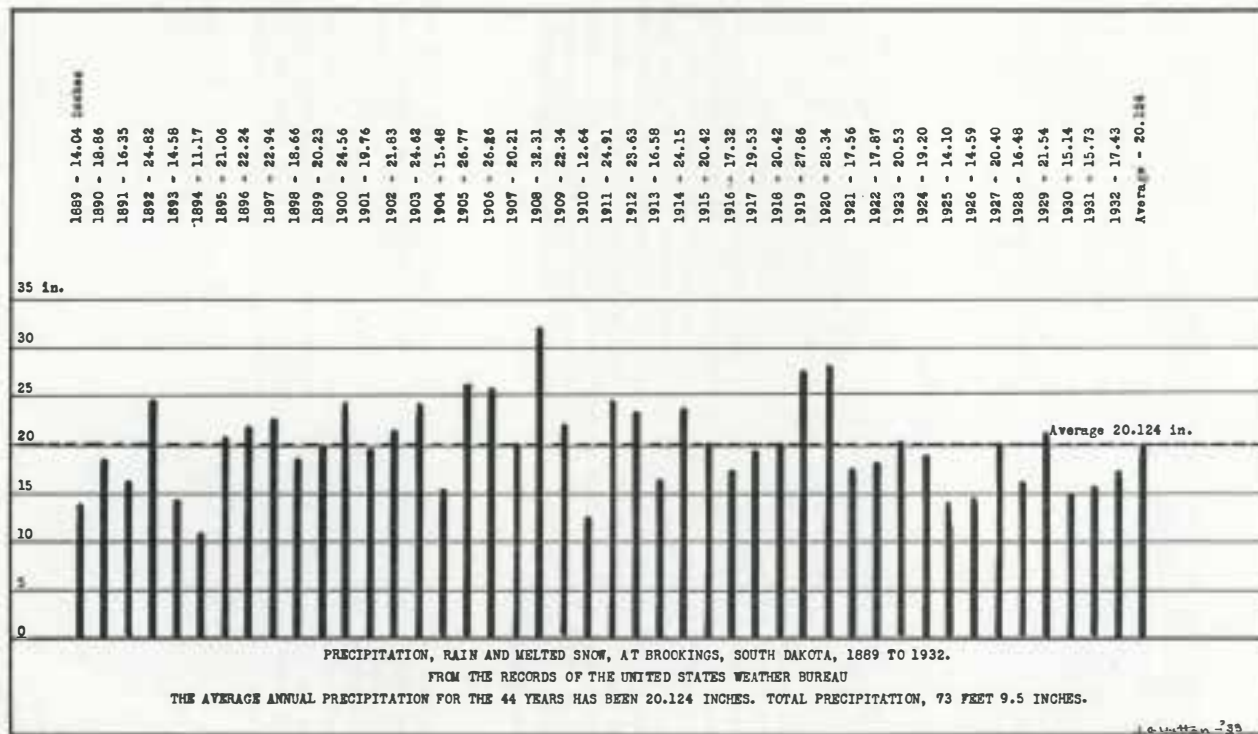


Fig. 8.—Annual Rainfall at Brookings, S. D., 1889 to 1932

Wise farmers will see to it that the fertility of the soil is maintained because soil ruin is upon us. In fact, it has already been taxing us more heavily than all other taxing agencies combined.

It should be understood that soil ruin is not only a problem of the future but of the present. In fact, this investigation shows that it has been with us for more than twenty years, because the very first application of phosphorus in this project gave a positive increase in crop yields.

Chemical analyses of soil samples taken from these plots in 1908 and at intervals of seven years since show the steady decrease in the fertility of the soil on the untreated plots. The results of soil and crop analyses will be published in another bulletin in the near future.

Conclusions

Many theories might be advanced to account for the yields of crops in response to applications of the different plant food combinations, but the discussion of this subject will be reserved for another occasion. It is probably enough to say that the data here published are worthy of close study, because they represent facts extending over so long a period of time.

A few tentative conclusions may be drawn from the facts which may serve as suggestions to those who are charged with the management and care of land.

1. The application of phosphorus alone has increased the yield of total crops produced 32.08%, or 1979 pounds per acre, over the yield from untreated soil. This is the largest return for any treatment.
2. The application of phosphorus alone has produced an increase of 74.80% in the total weight of the red clover crop including seed, straw, and hay. This is important in maintaining the nitrogen supply on the farm, as clover secures its nitrogen from the air rather than from the soil.
3. While rainfall is always an important factor in crop production, the application of phosphorus alone has increased the efficiency of the average annual rainfall at Brookings, S. D., for the twenty year period by 32.08%.
4. It seems that phosphorus may be economically applied to soil like that at Brookings, S. D., and under similar climatic conditions, when the additional 1977 pounds, approximately 1 ton, of crop per acre produced by its application is worth \$2.20 or more.
5. Phosphorus MUST be applied if the fertility of the soil is to be maintained.
6. The application of nitrogen and potassium, either singly or in combination with the other elements, has not paid for the expense involved.
7. The results recorded in this bulletin may offer valuable suggestions to those who are concerned with the effective management of soils and in maintaining their fertility.

NOTE: This project is still in progress and additional results will be published from time to time.

CORN

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

Treatment Plot No. Yield	Rot'n	None 140 or 150		N 141 or 151		P 142 or 152		K 143 or 153		None 144 or 154		NP 145 or 155		NK 146 or 156		PK 147 or 157		NPK 148 or 158		None 149 or 159		Average of None	
		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	2600	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
Av.	25	33.85	1290	39.38	1467	41.08	1650	36.08	1423	34.03	1333	36.98	1417	36.80	1400	38.98	1667	36.70	1757	33.65	1433	33.84	1352
Av.	27	34.80	1567	40.45	1567	42.18	1817	36.63	1617	36.33	1573	43.23	1767	38.08	1517	42.45	1873	46.43	2150	32.70	1608	34.61	1583
Av. 25&27	34.33	1428		39.91	1517	41.63	1733	36.35	1520	35.18	1453	40.10	1592	37.44	1458	40.71	1770	41.56	1953	33.18	1521	34.23	1468
Increase over																							
"Av. of None"				5.68	49	7.40	265	2.12	52			5.87	124	3.21	10*	6.48	302	7.33	485				
Increase per cent				16.59	3.34	21.62	18.05	6.12	3.54			17.15	8.45	9.38	.68*	18.93	20.57	21.41	33.04				

* Indicates decrease.

WHEAT

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

Treatment Plot No. Yield	Rot'n	None 140 or 150		N 141 or 151		P 142 or 152		K 143 or 153		None 144 or 154		NP 145 or 155		NK 146 or 156		PK 147 or 157		NPK 148 or 158		None 149 or 159		Average of None	
		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	3180	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
Av.		15.44	2118	16.60	2358	19.28	2337	14.68	1948	13.90	1822	17.67	2676	15.75	2517	17.77	2250	17.08	2457	14.17	2017	14.50	1985
Increase over																							
"Av. of None"				2.10	373	4.78	352	.18	37*			3.17	691	1.25	532	3.27	265	2.58	472				
Increase per cent				14.48	18.79	32.97	17.73	1.24	1.86*			21.86	34.81	8.62	21.14	22.55	13.35	17.79	23.78				

* Indicates decrease.

OATS

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

Treatment Plot No.	Yield No.	Rot'n	None		N		P		K		None		NP		NK		PK		NPK		None		Average of None	
			140 or 150 Grain Bu.	140 or 150 Straw Lbs.	141 or 151 Grain Bu.	141 or 151 Straw Lbs.	142 or 152 Grain Bu.	142 or 152 Straw Lbs.	143 or 153 Grain Bu.	143 or 153 Straw Lbs.	144 or 154 Grain Bu.	144 or 154 Straw Lbs.	145 or 155 Grain Bu.	145 or 155 Straw Lbs.	146 or 156 Grain Bu.	146 or 156 Straw Lbs.	147 or 157 Grain Bu.	147 or 157 Straw Lbs.	148 or 158 Grain Bu.	148 or 158 Straw Lbs.	149 or 159 Grain Bu.	149 or 159 Straw Lbs.	Grain Bu.	Straw 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	890	2.67	982
1912	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	39.70	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
Av.			33.85	1432	34.73	1628	43.92	1740	33.84	1421	33.48	1392	39.47	1686	34.42	1691	39.47	1667	35.60	1803	36.29	1484	34.54	1436
Increase over "Av. of None"					.19	192	9.38	304	.70*	15*			4.93	250	.12*	255	4.93	231	1.06	367				
Increase per cent					.55	13.37	27.16	21.17	2.03*	1.04*			14.27	17.41	.35*	17.76	14.27	16.09	3.07	25.56				

* Indicates decrease.

BARLEY

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

Treatment Plot No.	Yield	None		N		P		K		None		NP		NK		PK		NPK		None		Average of	
		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	None	Straw										
Year	Rot'n	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	Grain Bu.	Straw 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
Av.		29.91	1503	34.56	2006	39.11	1960	29.62	1542	27.54	1521	37.11	2094	31.14	1940	37.28	1778	38.73	2287	30.67	1547	29.38	1524
Increase over																							
"Av. of None"				5.18	482	9.73	436	.24	18			7.73	570	1.76	416	7.90	254	9.35	763				
Increase per cent				17.63	31.63	33.12	28.61	.82	1.18			26.31	37.40	5.99	27.30	26.89	16.67	31.82	50.07				

RED CLOVER

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

Treatment Plot No.		None		N		P		K		None		NP		NK		PK		NPK		None		Average of	
Yield		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		None	
Year	Rot'n	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 Lbs.
1914	25	70.0	760	85.0	1115	90.0	880	80.0	870	100.0	915	90.0	970	115.0	1065	100.0	765	130.0	1100	90.0	895	86.7	857
1914	27	110.0	1325	150.0	1410	170.0	1660	140.0	1370	120.0	1165	140.0	1725	130.0	1570	120.0	1540	140.0	2030	90.0	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	50.0	950	115.0	1585	200.0	2400	95.0	1605	130.0	1520	115.0	2265	130.0	2570	130.0	2970	100.0	2200	85.0	1595	88.3	1355
1924	27	55.0	1365	85.0	1635	165.0	2415	90.0	1710	95.0	1305	125.0	2875	145.0	1955	200.0	2440	140.0	2560	90.0	1410	80.0	1360
Av.	25	40.0	570	66.7	900	96.7	1093	58.3	825	76.7	812	68.3	1078	81.7	1212	76.7	1245	76.7	1100	58.3	830	58.3	737
Av.	27	55.0	897	78.3	1015	111.7	1358	76.7	1027	71.7	823	88.3	1533	91.7	1175	106.7	1327	93.3	1530	60.0	903	62.2	874
Av. 25&27		47.5	733	72.5	958	104.2	1226	67.5	926	74.2	818	78.3	1306	86.7	1193	91.7	1286	85.0	1315	59.2	867	60.3	806
Increase over "Av. of None"				12.20	152	43.90	420	7.20	120			18.0	500	26.4	387	31.4	480	24.7	509				
Increase per cent				20.23	18.86	72.80	52.11	11.94	14.89			29.85	62.03	43.78	48.01	52.07	59.55	40.96	63.15				

Red Clover Hay Crops By Cuttings and Totals

Year	Rot.	Cut.	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	
1914	27	1st	1720	1720	1580	1580	2820	2820	1760	1760	1700	1700	2820	2820	1570	1570	3170	3170	2420	2420	1500	1500	
1919	25	1st	2140		1630		2890		1680		1770		1130		1380		1870		1290		1490		
1919	25	2nd	3050		2950		3650		2400		2300		3150		2400		3250		2850		2450		
1919	25	Total		5190		4580		6540		4080		4070		4280		3780		5120		4140		3940	
1919	27	1st	1310		1100		3310		970		1140		470		390		1140		590		1000		
1919	27	2nd	2400		2600		3700		1950		2700		2600		1800		3000		2550		2550		
1919	27	Total		3710		3700		7010		2920		3840		3070		2190		4140		3140		3550	
1924	25	1st	1100		800		2490		1240		1100		750		850		2710		2710		640		
1924	27	1st	900		900		2730		1610		1610		870		750		1100		3430		2300		
Av.	25	1st	1523		1337		2887		1540		1587		1553		1347		2723		1710		1503		
Av.	27	1st	1310		1223		2953		1447		1493		1387		1020		2580		1770		1230		
Av.	25&27	1st	1417		1280		2920		1493		1540		1470		1183		2652		1740		1367		
Av.	25	2nd	3050		2950		3650		2400		2300		3150		2400		3250		2850		2450		
Av.	27	2nd	2400		2600		3700		1950		2700		2600		1800		3000		2550		2550		
Av.	25&27	2nd	2725		2775		3675		2175		2500		2875		2100		3125		2700		2500		
Av.	25	Total		2540		2320		4103		2340		2353		2603		2147		3807		2660		2320	
Av.	27	Total		2110		2090		4187		2097		2393		2253		1620		3580		2620		2080	
Av.	25&27	Total		2325		2205		4145		2218		2373		2428		1883		3693		2640		2200	
Increase (total) over "Av. of None"																							
Increase per cent							94*	1846		81*			129		416*		1394		341				
							4.09*	80.30		3.52*			5.61		18.09*		60.64		14.83				

NOTE: Owing to weather conditions during the summer of 1919 no seed formed and both cuttings of the clover crop were used for hay.

* Indicates decrease.

SUMMARY

TABLE 6.—Summary of the Results From All Treatments on All Crops—Corn, Wheat, Barley, Oats, Red Clover—in Rotations No. 25 and No. 27 at Brookings, S. D., Expressed as Weighted Averages

Crop No. of Years Treatment	Corn Grain ⁴		Corn Stalks ³		Wheat ⁹		Wheat Grain Straw ⁹		Barley ⁹		Barley Grain Straw ⁹		Oats ⁸		Oats Grain Straw ⁸		Clov. ³ Seed		Clov. ³ Straw		Clov. ³ Hay	
	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	34.23		1468		14.50		1985		29.38		1524		34.54		1436		60.3		806		2299	
N	39.41	5.68	1517	49	16.60	2.10	2358	373	34.56	5.18	2006	482	34.73	.19	1628	192	72.5	12.2	958	152	2205	94*
P	41.63	7.40	1733	265	19.28	4.78	2337	352	39.11	9.73	1960	436	43.92	9.38	1740	304	104.2	43.9	1226	420	4145	1846
K	36.35	2.12	1520	52	14.68	.18	1948	37*	29.62	.24	1542	18	33.84	.70*	1421	15*	67.5	7.2	926	120	2218	81*
NP	40.10	5.87	1592	124	17.67	3.17	2676	691	37.11	7.73	2094	570	39.47	4.93	1686	250	78.3	18.0	1306	500	2428	129
NK	37.44	3.21	1458	10*	15.75	1.25	2517	532	31.14	1.76	1940	416	34.42	.12*	1691	255	86.7	26.4	1193	387	1883	416*
PK	40.71	6.48	1770	302	17.77	3.27	2250	265	37.28	7.90	1778	254	39.47	4.93	1667	231	91.7	31.4	1286	480	3693	1394
NPK	41.56	7.33	1953	485	17.08	2.58	2457	472	38.73	9.35	2287	763	35.60	1.06	1803	367	85.0	24.7	1315	509	2640	341
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	16.59		3.34		14.48		18.79		17.63		31.63		.55		13.37		20.23		18.86		4.09*	
P	21.62		18.05		32.97		17.73		33.12		28.61		27.16		21.17		72.80		52.11		80.30	
K	6.19		3.54		1.24		1.86*		.82		1.18		2.03*		1.04*		11.94		14.89		3.52*	
NP	17.15		8.45		21.86		34.81		26.31		37.40		14.27		17.41		29.85		62.03		5.61	
NK	9.38		.68*		8.62		21.14		5.99		27.30		.35*		17.76		43.78		48.01		18.09*	
PK	18.93		20.57		22.55		13.35		26.89		16.67		14.27		16.09		52.07		59.55		60.64	
NPK	21.41		33.04		17.79		23.78		31.82		50.07		3.07		25.56		40.96		63.15		14.83	

NOTE: The figures indicating the greatest increase in yield in each crop are printed in bold faced type.

* Indicates decrease.

GENERAL SUMMARY

TABLE 7.—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 Twenty Years

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	4	19,169	22,350	23,313	20,356	22,456	20,966	22,798	23,274
Wheat	9	7,830	8,964	10,411	7,927	9,542	8,505	9,596	9,223
Barley	9	12,692	14,930	16,896	12,796	16,032	13,452	16,105	16,731
Oats	8	8,842	8,891	11,244	8,663	10,104	8,812	10,104	9,114
Cl. Seed	3	362	435	625	405	470	520	550	510
Total	20	48,895	55,570	62,489	50,147	58,604	52,255	59,153	58,852
Total Gain		-----	6,675	13,594	1,252	9,709	3,360	10,258	9,957
Av. Gain per Yr.		-----	334	679	62	485	168	513	498
Gain Per Cent		-----	13.65	27.80	2.56	19.86	6.87	20.98	20.36

		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	3	8,808	9,102	10,398	9,120	9,552	8,748	10,620	11,718
Wheat	9	17,865	21,222	21,033	17,532	24,084	22,650	20,250	22,113
Barley	9	13,716	18,054	17,640	13,878	18,846	17,460	16,002	20,583
Oats	8	11,488	13,024	13,920	11,368	13,488	13,528	13,336	14,424
Cl. Straw	3	4,836	5,748	7,356	5,556	7,836	7,158	7,716	7,890
Cl. Hay	3	13,794	13,230	24,870	13,308	14,568	11,298	22,158	15,840
Total	19	70,507	80,380	95,217	70,762	88,374	80,842	90,082	92,568
Total Gain		-----	9,873	24,710	255	17,867	10,335	19,575	22,061
Av. Gain per Yr.		-----	520	1,300	13	940	544	1,030	1,161
Gain Per Cent		-----	14.00	35.05	0.35	25.34	14.66	27.76	31.29

Total Amount of Dry Matter Produced Under the Several Treatments									
		Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay	Grain, Straw, Stalks & Hay
Corn		27,977	31,452	33,711	29,476	32,008	29,714	33,418	34,992
Wheat		25,695	30,186	31,444	25,459	33,626	31,155	29,846	31,336
Barley		26,408	32,984	34,536	26,674	34,878	30,912	32,107	37,314
Oats		20,330	21,915	25,164	20,031	23,592	22,340	23,440	23,538
Clover		18,992	19,413	32,851	19,269	22,874	18,976	30,424	24,240
Total		119,402	135,950	157,706	120,909	146,978	133,097	149,235	151,420
Total Gain		-----	16,548	38,304	1,507	27,576	13,695	29,833	32,018
Gain Per Cent		-----	13.86	32.08	1.26	23.10	11.47	24.99	26.82

General Summary of the Increases in Yield for the Several Treatments Over No Treatment for All Crops Grown									
Total Gain Grain 20 Years		6,675	13,594	1,252	9,709	3,360	10,258		9,957
Total Gain Straw, etc. 19 Years		9,873	24,710	255	17,867	10,335	19,575		22,061
Total Gain Dry Matter		16,548	38,304	1,507	27,576	13,695	29,833		32,018
Gain Per Cent Grain 20 Years		13.65	27.80	2.56	19.86	6.87	20.98		20.36
Gain Per Cent Straw, etc. 19 Years		14.00	35.05	0.36	25.34	14.66	27.76		31.29
Gain Per Cent Total Dry Matter		13.86	32.08	1.26	23.10	11.47	24.99		26.82