TEXAS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 190 JUNE, 1916

DIVISION OF CHEMISTRY

The Effect of Additions on the Availability of Soil Potash, and the Preparation of Sugar Humus

POSTOFFICE:

COLLEGE STATION, BRAZOS COUNTY, TEXAS.

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BY

G. S. FRAPS, Ph. D.,
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EFFECTS OF ADDITIONS ON THE AVAILABILITY OF SOIL POTASH AND THE PREPARATION OF SUGAR HUMUS.

By G. S. Fraps, Ph. D., Chemist in Charge; State Chemist.

It has for a long time been claimed that lime, carbonate of lime, gypsum, salt, organic matter, and the gypsum carried by acid phosphate, render soil potash much more available to plants. This is largely based upon the fact that sulphate of lime and other neutral salts replace the potash absorbed by soils and cause more of it to go into solution. Although this fact is well established, the conclusion does not necessarily follow that plants take up more potash under such conditions. On the other hand, it is quite possible that absorbed potash may be equally as available to plants, as that driven out of the compounds by neutral salts. It is of course likewise possible that various salts or substances may assist in the weathering of difficultly soluble silicates, and thereby assist potash in becoming available.

In considering this matter, we must make a distinction between the active potash of the soil, which is taken up by plants easily, and the insoluble potash, which is not easily taken up by plants. The availability of the active potash may be little affected, when the insoluble potash may be affected to some extent.

As an example of the claims made, Huston (International Congress of Applied Chemistry, 1912, 15, 139) claims that nitrate of soda and the gypsum in acid phosphate may release enough potash to supply the needs of the crop. The soda in 100 pounds nitrate of soda, he says, is capable of releasing 55 pounds of potash from zeolites, and the gypsum in 100 pounds of ordinary acid phosphate is capable of releasing 18 pounds of potash. If an application of 600 pounds of nitrate of soda and 300 pounds of acid phosphate per acre is made, "Expressed in terms of sulphate of potash, this is equivalent to the application of 768 pounds sulphate per acre; while the assumed crop only requires 120 pounds. It is not surprising that where these materials are used in experimenting there should be very frequent instances where the plot with nitrogen and phosphoric acid should give quite as good yields as those receiving all three elements, for the plot without potash has received material capable of releasing more than six times as much potash as the assumed crop requires."

This quotation is made for the purpose of showing the great claims made for the action of additions to the soil on the availability of its potash.

METHOD OF WORK.

The experiments here described were undertaken for the purpose of studying the effect of carbonate of lime, vegetable matter, and other substances upon the quantity of potash taken up by plants in pot experiments. The experiments were conducted in several series.

First Series.

Only one soil, No. 1290, was used in this series. The following additions were made to 5 kilogram pots: Sawdust (Saw), 25 grams; sugar humus (H), No. 1355, 20 grams. Precipitated chalk, calcium carbonate (VCa), 25 grams; corn cobs (Cobs), 25 grams. These additions, except the humus, were made at the rate of 5000 parts per million, or five tons to the acre, on a basis of two million pounds.

First Crop, Cotton.—One gram ammonium nitrate and 2.5 grams acid phosphate were added and 5 cotton seed, weighing 0.6-0.7 grams, planted June 2, 1908, harvested September 1.

Second Crop, Corn.—One gram ammonium nitrate and 2.5 grams acid phosphate were added and 5 grains corn weighing 1.8-1.9 grams, planted March 10, 1909, harvested June 9, 1909.

For results of this series, see Table 1. The results will be discussed in connection with the other series.

Second Series.

This series was begun in 1909 on two soils, and eight crops were grown in three years. Five thousand grams of soil were used. At the beginning of the experiment, besides the phosphoric acid and nitrogen mentioned below, the following additions were made: carbonate of lime (Ca) (precipitated chalk), 5.0 grams = 0.1% of the soil or 1000 parts per million; carbonate of lime (XCa), 50 grams=1% of the soil, or 10,000 parts per million; sulphate of lime (S), 5 grams; sulphate of lime (XS), 25 grams; sulphate of soda (Na), 5 grams; sulphate of soda (2Na), 10 grams; sugar humus (H), 5 grams; and sugar humus (VH), 25 grams.

First Crop, Corn.—One gram ammonium nitrate and 2.5 grams acid phosphate were added to all pots, and 5 grains corn weighing 2.0-2.1 grams were planted in each pot March 30. Crops were harvested June 18, dried, weighed as usual, and analyzed.

Second Crop, Sorghum.—One gram sorghum seed, planted June 21, harvested September 13; no additions made.

Third Crop, Corn.—One gram ammonium nitrate and 2.5 grams acid phosphate were added, and 5 grains corn weighing 1.3-1.4 grams were planted April 5; one gram ammonium nitrate added May 11; harvested June 17, 1910.

Fourth Crop, Sorghum.—One gram ammonium nitrate and 2.5 grams acid phosphate were added, and 1 gram sorghum planted June 21, 1910. Harvested August 22, 1910.

Fifth Crop, Oats.—One gram ammonium nitrate and 2 grams acid phosphate added and 1 gram oats planted October 13. Plants were killed by frost before any decided growth was made, and were harvested January 5, 1911.

Sixth Crop, Corn.—One gram ammonium nitrate and 2 grams acid phosphate were added and 5 grains corn weighing 2.0-2.1 grams were planted March 22, 1911. Harvested June 19.

Seventh Crop, Sorghum.—One gram ammonium nitrate added, and

1 gram sorghum planted June 26, 1911. The plants did very poorly on soil 1956. Harvested September 15, 1911.

Eighth Crop, Corn.—One gram ammonium nitrate and 2 grams acid phosphate added, and 5 grains corn weighing 1.7-1.8 grams planted April 3. Harvested June 20, 1912. The experiment was then discontinued, and all the soils prepared for analysis.

The results are presented in Tables 7 and 8, and summarized in Table 3. The results will be discussed in connection with the other series.

Third Series.

In this and subsequent series, dicalcium phosphate containing about 36 per cent. citrate-soluble phosphoric acid was used as a source of phosphoric acid instead of acid phosphate, on account of the objection, due to the gypsum carried in the latter, raised by Huston. The quantities of soil in the pots varied from 5900 to 8000 grams and are given below:

4579—7200 grams.
4583—7400 grams.
4597—7600 grams.
4642—5900 grams.
4649—8000 grams.

The pots were filled to the same depth. The difference in the weight is due to the difference in the density of the soils. Additions were made as follows: Carbonate of lime as precipitated chalk (Ca) 8 grams, or a little over 1000 parts per million; carbonate of lime (2Ca), 16 grams; sulphate of lime (CaS) 4 grains, or a little over 500 parts per million; manure, sheep excrement 4263 (M), 8 grams. This manure contained 3.97 per cent. lime, 1.36 per cent. magnesia, 1.07 per cent. phosphoric acid and 0.22 per cent. potash, and was derived from peanut hay.

First Crop, Corn.—Additions, 1 gram N (ammonium nitrate), 1 gram D (dicalcium phosphate). Planted corn, 5 grains, 1.6-1.7 grams, May 5, harvested July 7 to 14, 1911.

Second Crop, Sorghum.—Additions, 1 gram N. Planted 1 gram sorghum July 25, harvested September 23 to October 7, 1911.

Third Crop, Corn.—Additions, 1 gram N, 1 gram D. Planted 5 grains corn, weighing 1.7-1.8 grams, April 3, harvested June 25 to July 10, 1912. Soil 2353 discontinued.

Fourth Crop, Sorghum.—Added 1 gram N. Planted 1 gram sorghum July 2, 1914, harvested August 20, 1914.

Fifth Crop, Corn.—Added 1 gram N, 1 gram D. Planted 5 grains corn, weighing 2.0-2.1 gram April 10, harvested June 24, 1914. Discontinued.

Fourth Series.

Two soils (2349 and 4601) were used in this series. The additions to pot weighing 7700 grams were: manure 4559 (M) 10 grams, or 1300 parts per million; precipitated carbonate of lime (Ca) 3.0 grams, or 400 parts per million; 2Ca 6.0 grams; sulphate of lime (CaS) 3.0 grams; 2CaS 6.0 grams; carbonate of magnesia (Mg) 3.0 grams;

2Mg, 6.0 grams; D, 1 gram dicalcium phosphate; N, 1 gram ammonium nitrate.

Manure 4559 contained 0.63 per cent. lime, 0.26 per cent. magnesia, 0.42 per cent. phosphoric acid and 0.50 per cent. potash, and was derived from corn shucks.

One gram each ammonium nitrate and dicalcium phosphate were added to the first crop, sorghum; the third crop, corn, and the fifth crop, corn. To the other crops, 1 gram ammonium nitrate alone was added.

DESCRIPTION AND COMPOSITION OF SOILS.

1290. Norfolk Sand. Palestine, Texas, farm of Latimer and Ezell, Anderson County.

1809.—Soil from A. and M. College farm, Brazos County, depth not given; bottom land.

1956.—Sand from E. J. Kyle's farm between College Station and Bryan, Brazos County.

2353.—Norfolk Fine Sand Subsoil, depth 7-22 inches, 1½ miles south of Mt. Pleasant, Titus County, ½ mile southwest of Red Springs, farm of Mary Mays; good soil, rolling; light brown subsoil, good drainage.

4579.—Brown Mesquite Soil, depth 0-8 inches, 1½ miles south of Thornton; farm of Jno. B. Griffin, Limestone County, produces 25 bushels corn, ⅓ bale of cotton.

4583.—White Sand; depth 0-.13, 1 mile northeast of Detroit, Red River County, farm of C. C. Williams; good drainage, upland; produces 20 bushels corn, ¼ bale of cotton.

4599.—Very poor upland, depth 0.8 inches, 1 mile north of Willis, Montgomery County, farm of John Duke; produces 15 bushels corn or ⅓ bale cotton; does not pack or dry into clods, does not crack on drying, washes a little; no drainage except natural slope of the land; cultivated 18 years, represents 20 acres on farm, manure used, no increase noticed, very few full crops grown.

4642.—Moderate upland, depth 0-5 inches, 1½ miles south of depot, Troup, Smith County, farm of J. M. Slagle; gray sandy land, level, good results on corn and cotton; native vegetation; drains well in wet seasons and stands drought very well; does not pack much or wash; cultivated 20 years; represents 100 acres on farm; no green crops; 4 loads of manure used with good results.

4649.—Subsoil to very poor upland (4648), depth 6-16 inches; 1 mile west of Woodville, farm of Frank Barber, Tyler County; white sandy soil.

4601.—Poor upland, depth 0-8 inches, ½ mile southeast of Jacksonville, Cherokee County; farm of Henry Pearce; red clay soil; corn, cotton, and tomatoes grown; fertilizer increased cotton yield from ⅓ to ½ bale cotton per acre (i. e., ⅙ bale increase), packs; dries into clods; cracks and washes a little; cultivated 25 years; represents 50 acres of farm; no green crops turned under; 1 load manure per acre gave good increase.

2349.—Norfolk White Sandy Loam subsoil, depth 11-21 inches, 5 miles southeast of Mt. Pleasant, Titus County; farm of S. Dangerfield; light brown loam.

TABLE 1. COMPOSITION OF SOILS.

	Norfolk sand.	Soil from College farm.	Sand from Kyle's farm.	Norfolk fine sand.	Brown Mesquite sandy loam.	Upland white sandy soil.	Upland gray sand.	Upland gray sandy soil.	To 4648	Upland poor red clay.	Norfolk fine sandy loam.
	Surface 1290	Surface 1809	Surface 1956	Subsoil 2353	Surface 4579	Surface 4583	Surface 4599	Surface 4642	Subsoil 4649	Surface 4601	Subsoil 2349
Percent—											
Phosphoric Acid	.01	.033	.037	.020	.....	.015	.033	.025	.025	.08	.030
Nitrogen	.02	.108	.033	.021	.0744	.0316	.0470	.0520	.0132	.0422	.036
Potash	.08	.13	.07	.11	.20	.075	.075	.07	.035	.23	.22
Lime	.05	.59	.33	.12	.25	.07	.21	.09	.09	.10	.12
Magnesia	.03	.88	.06	.08	.33	.08	.06	.09	.05	.06	.16
Alumina and Oxide of Iron	1.31	6.56	1.01	1.44	7.04	2.66	.69	2.14	1.11	18.75	7.08
Insoluble and Soluble Silica	98.15	84.63	98.07	96.87	86.30	95.28	96.54	.....	97.80	70.64	87.25
Loss on Ignition	.61	.....	.....	.82	.....	1.33	1.65	1.77	.67	5.32	2.64
Moisture	0.84	.....	.....	.20	.....	.338	.45	.42	.12	4.82	1.10
Parts Per Million—											
Active Phosphoric Acid	21.2	77.9	75.3	51.5	19.0	19	50.1	23.8	10	4.3	1.9
Active Potash	90	228.1	105	106	159	83	136.0	169	74	118	113
Acidity	0	0	.....	0	300	300	100	300	200	300	0
Acid Consumed	24.5	12.0	1.48	1.01	6.5	1.0	1.85	2.0	1.0	3.5	2.85
Water capacity	.....	44.4	26.52	36.9	35.44	30.87	27.26	31.02	22.47	31.24	38.36

EFFECTS OF THE ADDITIONS ON THE POTASH TAKEN UP.

The general results of the experiment may be seen by referring to Tables 2, 3, 4, 5, and 6. The potash is expressed in the terms of bushels corn per acre, assuming that one bushel corn requires for stalk, leaves, and grain, one pound of potash, and a soil depth equal to two million pounds. Thus one part per million of potash is equal to two bushels corn, and .0025 grams from a pot of 5000 grams is equal to one bushel corn.

With the soil No. 1290, Table 2, the organic matter and the carbonate of lime are shown to cause an increase in the crop, and in the quantity of the potash taken up, the increased quantity of potash being 20 per cent. with the cobs, and 10 per cent. with the carbonate of lime. There is an increase in the crop with the sawdust, but no corresponding increase in the potash taken up.

With Soil No. 1809 (Table 3), none of the additions have any certain effect upon the increase. With Soil No. 1956, there is a small increase, due to the carbonate of lime, both in the quantity of potash (4 to 10 per cent.) and in the size of the crop. Sulphate of soda and the sulphate of lime in several cases caused a decrease in the size of the crop.

TABLE 2.—WEIGHT OF CROP AND POTASH TAKEN UP FROM SOIL 1290—SERIES 1.

	Weight of Crop.					Grams of Potash.					Gain of Potash expressed in bu. of corn per crop.
	Cotton 1908	Corn 1909	Total.	Average.	Gain over 0	Cotton.	Corn.	Total.	Average.	Gain over 0	
1–O	17.0	24.6	41.6	39.0	.....	.118	.096	.214	.252	.....	.....
2–O	16.3	20.0	36.3	.....	.....	.171	.118	.289	.....	.....	.....
3–Cob	20.0	21.6	41.6	46.2	7.2	.200	.149	.349	.351	.099	19.8
4–Cob	12.7	37.0	50.7	.....	.....	.154	.199	.353	.....	.....	.....
5–Ca	21.4	13.7	45.1	42.2	2.2	.244	.078	.322	.305	.053	10.1
6–Ca	15.8	23.5	39.3	.....	.....	.180	.108	.288	.....	.....	.....
7–Saw	18.7	25.5	44.2	44.9	5.9	.144	.098	.242	.251	0	0
8–Saw	17.9	27.6	45.5	.....	.....	.151	.108	.259	.....	.....	.....
9–H	13.7	16.0	29.7	27.7	0	.099	.107	.206	.218	0	0
10–H	13.7	12.0	25.7	.....	.....	.159	.071	.230	.....	.....	.....
11–HCa	17.0	27.5	44.5	43.5	4.5	.133	.129	.262	2.66	.014	2.8
12–HCa	20.0	22.5	42.5	.....	.....	.161	.108	.269	.....	.....	.....
Potash removed per crop	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	50.4

TABLE 3. AVERAGE GAINS DUE TO ADDITION.

Addition	Dry matter of crops.		Potash in grams.		Potash in bu. Corn per crop.	
	8 crops 1809	6 crops 1956	8 crops 1809	6 crops 1956	1809	1956
Carbonate of Lime	0	16.4	0	.0637	0	4
XCarbonate of Lime	4.1	18.7	0	.1493	0	10
Sulphate of Lime	0	0	.0436	0	2	0
XSulphate of Lime	0	0	.0011	0	0.05	0
Sulphate of Soda	0	0	0	0	0	0
XSulphate of Soda	0	0	0	0	0	0
Humus	1.1	0	.1115	.0272	6	2
VHumus	0	0	0	0	0	0
Carbonate of Lime and Humus	0	8.5	.0184	.0641	1	4
Carbonate of Lime and VHumus	0	8.2	0	.0532	0	3.5
Total weight with no addition	184.2	92.2	1.5984	0.6341	80	42

TABLE 4. GAINS DUE TO ADDITION—THIRD SERIES.

Addition	Total gain in dry matter—gms.						Gain in potash, bu. corn per acre. per crop.					
	2353	4579	4583	4599	4642	4649	2353	4579	4583	4599	4642	4649
Ca	5.4	0	5.1	0	11.5	0	4.6	0	1.6	.08	2.7	0.5
2Ca	.....	0	5.3	0	0	0	.....	0	0	0	2.8	0
CaS	0	0	0	0	0	0	0	0	0	0	0.8	0
M	4.9	0	13.9	0	19.6	33.9	4.6	1.2	.8	0	5.6	7.5
MCa	.....	0	8.5	0	15.5	.....	.....	0	2.4	0.8	2.4	3.0
Original weight	73.7	169.3	78.0	107.2	115.1	39.6	43	49	24.8	26.8	61.2	14.8
Number of crops	3	5	5	5	5	4						

TABLE 5. GAIN DUE TO ADDITION—FOURTH SERIES.

Laboratory Number.	Total gain in Dry Matter. Gms.		Gain in Potash in bu. corn per acre per crop.	
	4601	2349	4601	2349
Ca	10.8	0	6.4	0
2Ca	0	0	7.2	0
CaS	0	0	0	0
2CaS	0	0	0	0
M	6.0	0	1.2	4
Mg	8.6	12.3	3.2	0
2Mg	0	0	3.6	0
Mg-Ca	0	.....	0.2	.....
Original	85.8	114.1	52	28
No. crops	5	5		

TABLE 6. PERCENTAGE GAINS OF POTASH DUE TO CARBONATE OF LIME OR ORGANIC MATTER.

Laboratory Number.	Carbonate of Lime.	Organic Matter.
1290	20	40
1809	0	7
1956	10	5
2353	11	11
4579	0	2
4583	6	3
4599	0	0
4642	4	9
4649	3	50
4601	12	2
2349	0	14
Total	66	143
Average (11)	6	13

With soils 4579 and 4599, given in Table 4, there is no increase in any of the crops with any of the additions. In the other soils, there are small increases due both to the carbonate of lime and to the manure. The sulphate of lime caused no increase in any case. With reference to the manure, it must be remembered that it carries some plant food with it, including a small amount of potash.

In Table 5, it is seeen that the sulphate of lime has no effect, and the carbonate of lime affects one soil but not the other.

Table 6 is the summary table and shows the percentage gains of potash, either with carbonate of lime or with manure in per cent. of the potash removed in all the soils tested. With carbonate of lime, there was no gain with four soils, gains of less than 6 per cent. with three soils, and gains of more than 10 per cent. with four soils. The gains of 6 per cent. or less are left out of consideration, as they are too small to be of significance. Thus there is a gain in the amount of potash taken up by the crops in four of the eleven soils, or about 33 per cent. of the number of soil. The average gain with all the soils due to carbonate of lime is 6 per cent.

In the case of manure, cobs, or humus, there is no gain with one soil and gains of less than 7 per cent. with five soils. There are gains of 9 per cent. or over with five soils, or about 45 per cent. of the soils used. The average gain of potash is 13 per cent. There are greater gains with the manure than with the carbonate of lime.

TABLE 7. WEIGHT OF CROPS IN GRAMS, SOIL 1809.

Addition.	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Oats 1910	Corn 1911	Sorghum 1911	Corn 1912	Total.	Average.	Gain over 0.
1-O.....	41.0	14.0	32.5	38.7	1.7	21.7	11.6	10.7	171.9	.....	.....
2-O.....	43.5	14.3	37.0	43.2	1.9	23.1	16.4	17.1	196.5	184.2	.....
3-Ca.....	34.9	13.9	36.1	38.0	1.7	13.2	19.3	4.4	161.5	.....	.....
4-Ca.....	42.0	14.6	37.5	42.4	2.1	26.6	23.5	7.1	195.3	17.87	0
5-XCa ...	37.0	12.3	41.0	44.2	1.7	23.9	22.8	13.7	196.6	.....	.....
6-XCa...	37.1	11.4	38.5	36.9	2.2	24.5	17.2	12.2	180.0	188.3	4.1
7-S.....	37.1	10.2	39.0	42.0	1.5	25.5	12.6	5.9	173.8	.....	.....
8-S.....	38.8	11.5	37.7	44.2	2.3	25.2	19.7	10.5	189.9	181.9	0
9-XS.....	36.5	9.6	34.0	40.4	2.0	21.2	11.3	11.3	156.1	.....	.....
10-XS.....	42.7	9.7	34.4	39.2	2.0	11.6	17.0	12.2	168.8	162.5	0
11-Na.....	36.4	12.9	38.2	38.7	1.7	11.0	15.2	11.7	165.8	.....	.....
12-Na.....	30.1	11.7	40.7	25.9	1.9	12.4	18.1	7.1	147.9	156.9	0
13-2Na	39.4	11.3	23.0	35.7	1.5	4.0	1.5	8.2	124.6	.....	.....
14-2Na. ...	38.6	11.9	8.0	17.2	1.0	3.6	0.5	1.2	82.0	103.3	0
15-H.....	37.2	12.4	43.0	43.2	0.7	9.0	19.0	13.2	177.7	.....	.....
16-H.....	43.7	13.8	42.4	41.2	1.5	23.5	20.1	6.7	192.9	185.3	1.1
17-VH.....	36.5	10.3	44.	39.2	1.6	22.0	14.5	9.9	158.0	.....	.....
18-VH.....	34.7	12.2	35.5	39.9	1.7	14.2	21.3	9.1	168.6	163.3	0
19-CaH ...	38.3	13.9	39.0	37.5	1.2	23.1	19.0	11.0	183.0	.....	.....
20-CaH...	36.7	13.9	40.0	38.9	.....	22.4	21.2	8.8	181.9	182.5	0
21-CaVH ..	37.4	10.5	36.1	33.7	1.0	22.4	19.3	4.3	164.7	.....	.....
22-CaVH. .	34.6	11.3	41.5	37.4	.....	27.2	11.5	10.8	174.3	169.5	0

TABLE 8. WEIGHT OF CROPS IN GRAMS, SOIL 1956.

	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Oats 1910	Corn 1911	Total	Average	Gain over 0
1-O	30.3	4.5	26.3	20.4	0.9	20.0	102.4	.....	.....
2-O	26.9	5.9	23.7	19.7	0.8	4.9	81.9	92.2	.....
3-Ca	31.7	6.5	28.0	27.2	0.8	18.7	112.9	.....	.....
4-Ca	29.7	6.1	22.2	29.4	1.0	15.8	104.2	108..6	16.4
5-XCa	29.0	6.8	25.1	30.0	0.6	20.6	112.1	.....	.....
6-XCa	29.1	8.1	24.5	30.5	0.7	16.7	109.6	110.9	18.7
7-S	26.0	4.7	2.7	2.9	0.6	1.2	38.1	.....	.....
8-S	27.5	5.6	29.0	22.5	1.0	19.2	104.8	71.5	0
9-XS	31.2	4.7	7.0	1.2	1.0	1.8	46.9	.....	.....
10-XS	18.9	4.1	26.8	19.9	0.5	17.4	87.6	67.3	0
11-Na	31.1	6.4	22.9	10.7	0.8	0.2	72.1	.....	.....
12-Na	21.3	.8	7.0	22.2	0.8	2.4	54.5	63.3	0
13-2 Na	22.1	5.6	9.1	30.9	0.8	16.8	85.3	.....	.....
14-2 Na	15.2	5.5	20.2	15.7	0.8	0.2	57.6	71.5	0
15-H	22.3	4.7	29.5	20.9	0.5	19.2	97.1	.....	.....
16-H	27.3	4.4	22.5	13.5	.....	2.2	69.9	83.5	0
17-VH	24.7	4.0	23.5	16.7	.....	20.7	89.6	.....	.....
18-VH	19.8	4.3	10.0	11.2	0.8	2.3	48.4	69.0	0
19-CaH	27.1	5.3	26.6	24.7	1.0	18.3	103.0	.....	.....
20-CaH	26.6	5.5	24.7	28.4	1.9	11.3	98.4	100.7	8.5
21-XCaVH	29.6	4.1	25.5	29.7	0.7	11.9	101.5	.....	.....
22-XCaVH	23.8	4.2	28.1	26.4	1.0	15.7	99.2	100.4	8.2

TABLE 9. WEIGHT OF CROPS IN GRAMS, SOIL 2353.

	Corn 1911	Sorghum 1911	Corn 1912	Gain over 0.
1-O	48.5	16.4	8.8	.....
2-Ca	45.3	26.0	7.8	5.4
3-CaS	48.1	12.4	4.9	0
4-M	48.2	24.5	5.9	4.9

TABLE 10. WEIGHT OF CROPS PER POT, SOIL 4579.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.
1-O	54.1	36.3	36.2	8.3	31.2	166.1	169.3	.....
2-O	50.8	36.9	37.2	10.7	37.7	173.3	.....	.....
3-Ca	40.9	34.0	36.0	13.6	38.3	162.8	156.9	0
4-Ca	43.4	38.2	19.8	7.7	41.2	150.3	.....	.....
5-2Ca	46 3	34.1	21.4	5.4	33.2	140.4	140.4	0
6-CaS	55 1	28.6	29.0	12.0	29.8	154.5	154.5	0
7-M	51.7	34.9	31.4	12.1	36.2	166.3	166.7	0
8-M	51.1	42.6	26.9	10.7	36.2	167.5	.....	.....
9-MCa	51.1	34.6	28.8	10.7	34.9	160.1	160.1	0

TABLE 11. WEIGHT OF CROPS, SOIL 4583.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.
1-O	44.4	8.4	10.6	1.4	11.5	76.3	78.0	.....
2-O	43.2	6.8	13.5	1.9	14.3	79.7	.....	.....
3-Ca	32.1	17.6	14.2	9.6	17.2	87.7	83.1	5.1
4-Ca	31.5	15.7	10.8	5.3	15.3	78.6	.....	.....
5-2Ca	38.9	12.4	10.7	3.6	17.7	83.3	83.3	5.3
6-CaS	43.3	4.4	7.7	0.8	5.0	61.2	61.2	0
7-M	41.7	10.0	12.4	2.2	26.5	92.8	91.9	13.9
8-M	45.9	9.9	11.2	1.3	22.7	91.0	.....	.....
9-MCa	36.5	15.2	10.3	6.3	18.2	86.5	86.5	8.5

TABLE 12. WEIGHT OF CROPS, SOIL 4599.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.
1–O	41.9	20.2	17.0	6.9	17.4	103.4	107.2	.....
2–O	44.0	21.7	19.0	11.0	15.4	111.1	.....	.....
3–Ca	27.3	18.5	6.3	10.5	15.9	78.5	83.7	0
4–Ca	27.8	18.5	7.0	12.5	23.0	88.8	.....	.....
5–2Ca	32.9	22.8	11.2	7.8	17.9	92.6	89.8	0
6–2Ca	22.9	20.6	12.6	11.9	19.0	87.0	.....	.....
7–CaS	33.8	7.9	12.0	10.4	14.3	78.4	81.7	0
8–CaS	40.1	11.0	12.8	5.0	16.0	84.9	.....	.....
9–M	36.9	20.3	10.3	7.7	16.5	91.7	95.1	0
10–M	39.1	17.6	12.3	11.3	22.1	102.4	.....	.....
11–MCa	39.5	17.0	14.1	10.3	24.3	105.2	101.1	0
12–MCa	37.0	16.8	12.8	11.2	19.2	97.0	.....	.....
Period of growth	May 5 –July 9	July 25 –Sept. 23	April 3 –June 13	July 2 –Aug. 20	April 10 –June 24			
Addition	RDN	N	DN	N	MDN			

TABLE 13. WEIGHT OF CROPS, SOIL 4642.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.
1–O	41.3	29.4	15.5	12.4	13.2	111.8	115.1	.....
2–O	38.0	30.8	22.8	12.3	14.5	118.4	.....	.....
3–Ca	30.0	33.3	22.3	13.3	28.4	127.3	126.6	11.5
4–Ca	33.8	26.0	28.2	18.5	19.5	125.8	.....	.....
5–2Ca	20.3	28.6	28.1	12.3	26.0	115.3	112.4	0
6–2Ca	26.4	26.1	22.0	13.2	21.8	109.5	.....	.....
7–CaS	39.2	34.5	14.7	4.7	19.4	112.5	115.3	0
8–CaS	41.6	36.1	18.5	3.0	18.9	118.1	.....	.....
9–M	34.1	33.9	32.7	11.0	23.6	135.3	134.7	19.6
10–M	35.9	43.3	21.0	11.5	22.4	134.1	.....	.....
11–CaM	28.7	32.5	23.7	11.1	31.9	127.9	130.6	15.5
12–CaM	36.9	25.0	30.0	18.5	22.8	133.2	.....	.....

TABLE 14. WEIGHT OF CROPS, SOIL 4649.

	Corn 1911	Sorghum 1911	Corn 1912	Corn 1913	Total.	Gain over 0.
1–O	24.5	5.9	2.7	6.5	39.6	.....
2–Ca	5.2	8.8	5.3	7.7	27.0	0
3–2Ca	11.2	5.0	5.0	7.6	28.8	0
4–CaS	22.1	0.1	0.1	2.7	25.0	0
5–2CaS	17.2	0.3	0.6	0.2	18.3	0
6–M	29.5	13.8	4.5	25.7	73.5	33.9
7–M2Ca	9.0	4.8	10.4	18.7	42.9	3.3

TABLE 15. WEIGHT OF CROP, SOIL 4601.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.
1–O	30.5	29.5	7.6	2.7	17.4	87.7	85.8	.....
2–Ca	23.3	25.2	5.1	19.8	33.2	106.6	106.6	10.8
3–2Ca	23.6	23.6	5.2	8.8	18.4	79.6	79.6	0
4–Mg	18.7	28.2	8.1	11.1	22.5	88.6	94.6	8.6
5–2Mg	18.4	27.6	8.3	9.1	13.0	76.4	76.4	0
6–M	26.2	27.0	9.3	1.0	22.7	86.2	91.8	6.0
7–M	24.2	30.1	10.2	10.2	22.7	97.4	.....	.....
8–O	30.7	15.2	8.7	12.7	16.6	83.9	.....	.....
9–Mg	19.9	30.3	9.5	11.6	29.0	100.3	.....	.....
10–MgCa	13.5	22.3	6.4	12.7	16.5	71.4	71.4	0
11–CaS	27.6	19.4	6.6	0.1	11.7	65.4	65.4	0
12–2CaS	22.5	27.8	6.4	0.1	8.7	65.5	65.5	0

TABLE 16. WEIGHT OF CROPS IN GRAMS, SOIL 2349.

Additions	Sorghum 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Gain over 0.
1–O	30.8	5.6	31.5	4.7	41.5	114.1	.....
2–Ca	13.3	2.0	36.5	15.9	41.9	109.6	0
3–2 Ca	7.1	1.3	31.8	14.3	42.0	96.5	0
4–CaS	23.6	1.0	15.8	0.1	17.4	57.0	0
5–2 CaS	16.6	1.0	12.3	3.4	21.2	54.5	0
6–Mg	16.1	9.0	49.5	7.8	44.0	126.4	12.3
7–2 Mg	10.5	2.4	45.1	14.0	21.8	93.8	0
8–Manure	34.6	1.8	26.6	7.5	35.0	105.5	0

TABLE 17. PERCENTAGE OF POTASH IN CROPS GROWN ON SOIL 1809.

Additions	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Corn 1911	Sorghum 1911	Corn 1912
1–O	1.85	1.06	0.84	.50	.34	.55	.48
2–O	1.85	.98	0.66	.48	.33	.55	.41
3–Ca	1.56	1.07	0.66	.40	.32	.57	.38
4–Ca	1.56	.69	0.68	.46	.34	.53	.44
5–XCa	1.75	1.05	0.80	.48	.29	.54	.39
6–XCa	2.00	.80	0.92	.50	.33	.53	.36
7–S	2.17	1.09	0.73	.52	.50	.49	.44
8–S	2.09	1.05	0.80	.42	.35	.47	.46
9–XS	2.10	1.13	0.90	.52	.34	.46	.37
10–XS	1.93	.95	1.02	.46	.44	.56	.38
11–Na	2.29	.97	0.64	.62	.48	.52	.43
12–Na	2.53	1.01	0.60	.60	.34	.59	.39
13–2 Na	2.24	1.04	0.80	.47	.36	.60	.51
14–2 Na	2.20	1.05	1.82	.74	.64	.48	.78
15–H	2.13	1.06	0.60	.62	.46	.52	.45
16–H	2.07	.97	0.66	.54	.41	.54	.34
17–VH	2.22	1.02	0.58	.45	.35	.53	.40
18–VH	2.32	.97	0.88	.46	.40	.48	.45
19–CaH	2.04	.93	0.71	.51	.44	.50	.39
20–CaH	2.18	.96	0.68	.54	.33	.46	.40
21–CaVH	2.14	.86	0.73	.48	.34	.51	.35
22–CaVH	2.01	.92	0.58	.50	.44	.60	.36

Our conclusion from this experiment is, that while carbonate of lime or manure may aid in rendering a portion of the insoluble potash of the soil available to plants, they have little or no effect upon the active potash by driving it out of solution or causing it to go into the plants more easily, as has hitherto been assumed. If the potash were driven out, we should expect the sulphate of lime to be as equally effective as the carbonate of lime, or more so. As a matter of fact, the sulphate of lime increased the quantity of potash taken up by the plants in only a very few cases. The effect of the carbonate of lime and also of the organic matter is, therefore, probably to render the soil conditions more favorable to the growth of plants, thereby increasing the general growth and the quantity of potash naturally taken up, though it may also affect the quantity taken from the silicates. This is quite different from the generally assumed action of driving fixed potash from solution and causing it to be more readily taken up. With all, except soils 1290, 1809, and 1956, dicalcium phosphate was used as a source of phosphoric acid to avoid the introduction of sulphate of lime with the acid phosphate. It has been claimed by Huston that this would affect the results, but these experiments do not justify such claims.

PERCENTAGE OF POTASH IN THE CROPS.

Tables 17-26 show the percentages of potash in the various crops harvested. The effect of the additions is sometimes to increase the percentages of potash and sometimes to decrease the percentages. An increase in the percentage of potash is very often accompanied by a decrease in the size of the crop. For example, crops grown on Soil No. 1956, Pots 13-14, contain higher percentages of potash than the crops to which no additions were made, but the size of the crop is smaller where the percentage of potash is larger. The same relations can be shown in other soils. For example, with Soil No. 4583, the application of carbonate of lime decreased the size of the crop from about 44 to about 32 grams, but it increased the potash from about .70 to about .92 per cent. Thus the decrease in the size of the crop is accompanied by an increase in the percentage of potash in the plant. Soil No. 4599 shows this in a very decisive way with the application of carbonate of lime, the yield of crop being about 27 grams with carbonate of lime and 43 grams without it, and the percentages of potash being about 2.30 with carbonate of lime and 1.41 without it. The quantity of potash taken up is slightly larger where the carbonate of lime was added than without it, although the size of the crop is reduced more. At the end of the series, however, there is practically no difference in the amount of potash taken up by the crops without carbonate of lime and that taken up by the crops with carbonate of lime, on this particular soil.

TABLE 18. PER CENT POTASH IN CROPS GROWN ON SOIL 1956.

Additions	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Corn 1911
1-O	.97	1.22	.60	.54	.40
2-O	.94	1.11	.50	.50	.79
3-Ca	.88	.96	.50	.54	.31
4-Ca	1.14	1.12	.41	.55	.32
5-XCa	1.24	.88	.54	.51	.39
6-XCa	1.12	.82	.58	.60	.30
7-S	1.24	.87	.60	1.20	1.84
8-S	1.24	.72	.65	.74	.27
9-XS	1.10	1.03	1.17	.42	1.58
10-XS	1.24	1.62	.92	.57	.35
11-Na	1.14	1.06	1.00	.46	.....
12-Na	.94	1.28	1.30	.42	.68
13-2 Na	1.40	.83	.96	.47	.35
14-2 Na	1.20	.93	.70	.31	.....
15-H	1.76	1.13	.50	.50	.36
16-H	1.06	1.16	.60	.44	.94
17-VH	1.12	1.41	.59	.31	.34
18-VH	.85	1.15	1.04	.27	.....
19-CaH	1.00	1.26	.62	.67	.39
20-CaH	1.00	1.24	.61	.42	.45
21-XCaVH	1.01	.99	.59	.57	.50
22-XCaVH	1.11	1.16	.56	.44	.45

TABLE 19. PER CENT POTASH IN CROPS ON SOIL 2353.

Additions	Corn 1911	Sorghum 1911	Corn 1912
1–O	.79	.48	.29
2–Ca	.92	.40	.29
3–CaS	.82	.47	.30
4–M	.87	.42	.27

TABLE 20. PER CENT POTASH IN CROPS ON SOIL 4579

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913
1–O	.86	.46	.43	.49	.31
2–O	.78	.48	.34	.41	.30
3–Ca	1.15	.46	.29	.50	.29
4–Ca	1.04	.48	.29	.46	.28
5–2 Ca	1.07	.48	.32	.68	.37
6–CaS	.85	.54	.36	.44	*.30
7–M	1.02	.51	.31	.41	*.30
8–M	.84	.49	.26	.42	*.30
9–MCa	.94	.46	.32	.41	.30

*Assumed.

TABLE 21. PER CENT POTASH IN CROPS ON SOIL 4583.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912
1–O	.74	.46	.41	.74
2–O	.67	.47	.34	.69
3–Ca	.93	.38	.35	.60
4–Ca	.91	.24	.38	.50
5–2 Ca	.75	.39	.38	.76
6–CaS	.77	.54	.34	.....
7–M	.69	.36	.41	.35
8–M	.66	.39	.39	.57
9–MCa	.83	.37	.37	.55

TABLE 22. PER CENT POTASH IN CROPS ON SOIL 4599.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913
1–O	1.41	.49	.35	.62	.27
2–O	1.41	.59	.45	.47	.43
3–Ca	2.29	.55	.41	.43	.46
4–Ca	2.36	.50	.52	.39	.39
5–2 Ca	1.88	.52	.42	.47	.30
6–2 Ca	2.64	.62	.36	.46	.35
7–CaS	1.95	.97	.45	.44	.38
8–CaS	1.65	.68	.42	.58	.40
9–M	1.66	.53	.42	.54	.31
10–M	1.57	.51	.42	.42	.29
11–MCa	1.52	.75	.43	.42	.34
12–MCa	1.62	.76	.47	.46	.35

TABLE 23. PER CENT POTASH IN CROPS IN SOIL 4642.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913
1-O	1.31	.66	.35	.54	.39
2-O	1.43	.56	.31	.58	.25
3-Ca	1.53	.70	.36	.56	.29
4-Ca	1.50	.76	.30	.56	.31
5-2Ca	2.34	.75	.38	.62	.28
6-2 Ca	1.89	.81	.50	.52	.25
7-CaS	1.47	.55	.47	.71	.19
8-CaS	1.39	.57	.45	.52	.25
9-M	1.46	.59	.47	.66	.25
10-M	1.45	.56	.38	.71	.26
11-CaM	1.82	.54	.38	.43	.25
12-CaM	1.39	.71	.37	.46	.29

TABLE 24. PER CENT POTASH IN CROPS ON SOIL 4649.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Corn 1913
1-O	.74	.63	.36	.52
2-Ca	2.92	.55	.39	.67
3-2 Ca	1.52	.64	.20	.37
4-CaS	.92	.....	.....	1.03
5-2 CaS	1.15	.....	.....	.....
6-M	.73	.50	.25	.37
7-M2Ca	1.84	1.29	.22	.33

TABLE 25. PER CENT POTASH IN CROPS ON SOIL 4601.

Additions	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913
1-O	.96	.39	.54	.38	.12
2-Ca	1.15	.54	.68	.50	.31
3-2 Ca	1.25	.61	.50	.37	.27
4-Mg	1.69	.50	.59	.32	.21
5-2 Mg	1.48	.59	.52	.62	.38
6-M	1.16	.39	.46	.65	.34
7-M	1.40	.40	.56	.52	.31
8-O	1.07	.56	.55	.40	.34
9-Mg	1.25	.45	.56	.39	.31
10-MgCa	1.63	.68	.57	.60	.26
11-CaS	1.18	.48	.53	.....	.41
12-2 CaS	1.41	.41	.59	.....	.46

TABLE 26. COMPOSITION. PER CENT POTASH SOIL 2349.

Additions	Sorghum 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.
1-O	1.74	1.18	.57	.54	.30	4.33
2-Ca	2.07	1.44	.90	.66	.39	5.46
3-2 Ca	2.00	1.44	1.49	.73	.46	6.12
4-CaS	1.88	1.25	1.21	.....	.76	5.10
5-2 CaS	2.06	1.20	1.79	.93	.68	6.66
6-Mg	2.38	1.28	.51	.39	.33	4.89
7-2 Mg	2.02	1.40	.94	.63	.49	5.48
8-Manure	1.71	1.43	.68	.83	.42	5.07

The percentages of potash in the crops are also found to decrease with each successive crop grown. Thus, in Soil No. 4599, the percentage of potash with the first crop, no addition, is 1.41, and with the

last crop, both of them being corn, is 0.35. The same general tendency is manifest in all the crops, there being a high percentage in the first crop and a low percentage in the last. The first crops evidently took up an excess of potash, when the amount of active potash in the soil was larger. As the quantity of active potash decreased, the percentage of potash taken up by the plant also decreased. We have pointed out this fact in other publications. The percentage of potash in the crops can in fact be taken to represent very roughly the deficiency of the soil in potash, provided the crop is a normal crop and is grown under normal conditions. The relation between the active potash of the soil and the potash content of the crop is brought out in Table 37. The relation holds only in a general way, since with the same quantity of active potash in the soil any influence which reduces the size of the crop may increase the percentage of potash in it.

TABLE 27. GRAMS POTASH TAKEN UP BY CROPS, SOIL 1809.

	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Corn 1911	Sorghum 1911	Corn 1912	Total.	Average.	Gain over 0.
1–O	.759	.1489	.2730	.1935	.0738	.0638	.0514	1.5634	.....	.....
2–O	.805	.1406	.2442	.2074	.0762	.0902	.0701	1.6333	1.5984	.....
3–Ca	.545	.1487	.2383	.1520	.0422	.1100	.0167	1.2529	.....	.....
4–Ca	.656	.1011	.2550	.1950	.0904	.1245	.0312	1.4532	1.3531	0
5–XCa	.648	.1297	.3280	.2122	.0693	.1231	.0534	1.5637	.....	.....
6–XCa	.742	.0912	.3542	.1845	.0809	.0912	.0439	1.5879	1.5758	0
7–S	.806	.1117	.2847	.2184	.1275	.0617	.0260	1.6360	.....	.....
8–S	.811	.1207	.3016	.1856	.0882	.0926	.0483	1.6480	1.6420	.0436
9–XS	.767	.1090	.3060	.2101	.0721	.0520	.0418	1.5580	.....	.....
10–XS	.825	.0921	.3509	.1803	.0510	.0952	.0464	1.6409	1.5995	.0011
11–Na	.834	.1256	.2465	.2399	.0528	.0790	.0503	1.6281	.....	.....
12–Na	.765	.1182	.2442	.1554	.0422	.1068	.0277	1.4592	1.5437	0
13–2Na	.883	.1180	.2040	.1678	.0144	.0090	.0418	1.4380	.....	.....
14–2Na	.849	.1249	.1456	.1273	.0230	.0024	.0093	1.2815	1.3598	0
15–H	.793	.1314	.2580	.2678	.0414	.0988	.0594	1.6498	.....	.....
16–H	.906	.1339	.2798	.2225	.0964	.1085	.0228	1.7699	1.7099	.1115
17–VH	.804	.1061	.2552	.1764	.0770	.0769	.0396	1.5352	.....	.....
18–VH	.805	.1183	.3124	.1835	.0568	.1022	.0410	1.6192	1.5772	0
19–CaH	.781	.1297	.2769	.1912	.1016	.0950	.0429	1.6175	.....	.....
20–CaH	.794	.1334	.2720	.2101	.0739	.0975	.0352	1.6161	1.6168	.0184
21–CaVH	.801	.0907	.2635	.1618	.0762	.0984	.0151	1.5067	.....	.....
22–CaVH	.693	.1039	.2407	.1870	.1197	.0690	.0389	1.4522	1.4795	0

TABLE 28. GRAMS POTASH TAKEN FROM SOIL 1956.

	Corn 1909	Sorghum 1909	Corn 1910	Sorghum 1910	Corn 1911	Total.	Average.	Gain over 0.
1–O	.291	.0549	.1578	.1102	.0800	.6939	.....	.....
2–O	.253	.0655	.1185	.0985	.0387	.5742	.6341	.....
3–Ca	.279	.0624	.1400	.1469	.0580	.6833	.....	.....
4–Ca	.340	.0689	.0910	.1617	.0506	.7122	.6778	.0637
5–XCa	.360	.0603	.1355	.1530	.0803	.7891	.....	.....
6–XCa	.336	.0664	.1421	.1830	.0501	.7776	.7834	.1493
7–S	.326	.0409	.0162	.0348	.0221	.4400	.....	.....
8–S	.341	.0407	.1885	.1665	.0518	.7855	.6128	0
9–XS	.344	.0489	.0891	.0050	.0284	.5082	.....	.....
10–XS	.235	.0672	.2466	.1134	.0609	.7231	.6157	0
11–Na	.355	.0684	.2290	.0492	.....	.7016	.....	.....
12–Na	.200	.0010	.0910	.0932	.0163	.4015	.5516	0
13–2Na	.310	.0469	.0874	.1452	.0588	.6483	.....	.....
14–2Na	.183	.0511	.1414	.0487	.....	.4242	.5363	0
15–H	.392	.0537	.1475	.1045	.0691	.7668	.....	.....
16–H	.289	.0516	.1350	.0594	.0207	.5557	.6613	.0272
17–VH	.277	.0571	.1387	.0518	.0704	.5950	.....	.....
18–VH	.175	.0494	.1040	.0302	.....	.3558	.4754	0
19–CaH	.272	.0674	.1649	.1655	.0714	.7412	.....	.....
20–CaH	.266	.0682	.1507	.1193	.0509	.6551	.6982	.0641
21–XCaVH	.299	.0406	.1505	.1693	.0595	.7189	.....	.....
22–XCaVH	.262	.0493	.1574	.1162	.0707	.6556	.6873	.0532

TABLE 29. GRAMS POTASH FROM SOIL 2353.

	Corn 1911	Sorghum 1911	Corn 1912	Total.	Gain over 0.	Per million from soil
1–O	.3831	.0787	.0255	.4873	.....	65
2–Ca	.4168	.1040	.0226	.5434	.0561	72
3–CaS	.3944	.0583	.0147	.4674	0	62
4–M	.4193	.1029	.0159	.5381	.0508	72

TABLE 30. GRAMS POTASH FROM SOIL 4579.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.	Per million of soil.
1–O	.4653	.1670	.1557	.0407	.0967	.9254	.8900	.....	128
2–O	.3939	.1771	.1265	.0439	.1131	.8545	.....	.....	119
3–Ca	.4704	.1564	.1044	.0680	.1111	.9103	.8766	0	126
4–Ca	.4514	.1834	.0574	.0354	.1154	.8430	.....	.....	117
5–2Ca	.4954	.1637	.0685	.0367	.1228	.8871	.8871	0	122
6–CaS	.4684	.1544	.1044	.0528	*.0894	.8694	.8694	0	121
7–M	.5273	.1780	.0973	.0496	*.1086	.9608	.9110	.0210	133
8–M	.4292	.2087	.0699	.0449	*.1086	.8613	.....	.....	121
9–MCa	.4803	.1592	.0922	.0439	*.1047	.8803	.8803	0	124

*Assumed.

TABLE 31. GRAMS OF POTASH FROM SOIL 4583.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain	Gain over M	Parts per million of soil.
1–O	.3286	.0386	.0435	.0104	.0564	.4775	.4554	.....	.....	64
2–O	.2894	.0320	.0459	.0131	.0529	.4333	.....	.....	.....	59
3–Ca	.2985	.0669	.0497	.0576	.0550	.5277	.4835	.0281	.....	71
4–Ca	.2866	.0377	.0410	.0265	.0474	.4392	.....	.....	.....	60
5–2Ca	.2139	.0484	.0406	.0274	.0903	.4206	.4206	0	.....	57
6–CaS	.3334	.0238	.0262	.....	.0380	.4214	.4214	0	.....	57
7–M	.2877	.0360	.0508	.0077	.0875	.4697	.4698	.0134	.....	63
8–M	.3029	.0386	.0437	.0074	.0772	.4698	.....	.....	.....	63
9–MCa	.3029	.0562	.0381	.0346	.0637	.4955	.4955	.0401	.0267	67

TABLE 32. GRAMS OF POTASH FROM SOIL 4599.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.	Per million of soil
1–O	.5908	.0990	.0595	.0428	.0470	.8391	.8955	.....	110
2–O	.6204	.1280	.0855	.0517	.0662	.9518	.....	.....	125
3–Ca	.6252	.1017	.0258	.0452	.0731	.8710	.8972	.0016	115
4–Ca	.6561	.0925	.0364	.0487	.0897	.9234	.....	.....	121
5–2Ca	.6185	.1186	.0470	.0367	.0537	.8745	.8862	0	115
6–2Ca	.6046	.1277	.0454	.0547	.0665	.8989	.....	.....	118
7–CaS	.4446	.0766	.0540	.0458	.0543	.6753	.7793	0	90
8–CaS	.6617	.0748	.0538	.0290	.0640	.8833	.....	.....	117
9–M	.6125	.1076	.0433	.0416	.0512	.8562	.8616	0	112
10–M	.6139	.0898	.0517	.0475	.0641	.8670	.....	.....	115
11–MCa	.6004	.1275	.0606	.0433	.0826	.9144	.9104	.0149	120
12–MCa	.5994	.1277	.0602	.0515	.0672	.9060	.....	.....	119

TABLE 33. GRAMS OF POTASH FROM SOIL 4642.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.	Per million of soil.
1–O	.5410	.1940	.0542	.0669	.0515	.9076	.9009	.....	153
2–O	.5434	.1725	.0707	.0713	.0363	.8942	.....	.....	151
3–Ca	.4590	.2331	.0803	.0745	.0824	.9293	.9413	.0404	156
4–Ca	.5070	.1976	.0846	.1036	.0605	.9533	.....	.....	162
5–2Ca	.4750	.2145	.1068	.0763	.0728	.9454	.9444	.0435	160
6–2Ca	.4990	.2114	.1100	.0686	.0545	.9435	.....	.....	160
7–CaS	.5762	.1898	.0691	*.0334	.0369	.9054	.9128	.0119	153
8–CaS	.5782	.2058	.0833	.0156	.0473	.9302	.....	.....	157
9–M	.4979	.2000	.1537	.0726	.0590	.9832	.9830	.0821	166
10–M	.5206	.2425	.0798	.0816	.0582	.9827	.....	.....	166
11–CaM	.5223	.1755	.0901	.0477	.0798	.9154	.9340	.0331	155
12–CaM	.5129	.1775	.1110	.0851	.0661	.9526	.....	.....	162

*CaO also.

TABLE 34. GRAMS OF POTASH FROM SOIL 4649.

	Corn 1911	Sorghum 1911	Corn 1912	Corn 1913	Total.	Gain over 0.	Per million of soil.
1–O	.1813	.0372	.0097	.0338	.2620	.....	33
2–Ca	.1518	.0484	.0206	.0516	.2724	.0104	34
3–2Ca	.1702	.0320	.0100	.0281	.2385	0	30
4–CaS	.2033	.....	.....	.0278	.2311	0	29
5–2CaS	.1978	.....	.....	.....	.1978	0	25
6–M	.2154	.0690	.0112	.0951	.3907	.1287	49
7–M2Ca	.1656	.0619	.0229	.0617	.3121	.0501	39

TABLE 35. GRAMS OF POTASH FROM SOIL 4601.

	Corn 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Average.	Gain over 0.	Per million of soil
1–O	.2928	.1151	.0410	.0103	.0209	.4801	.5245	.....	66
2–Ca	.2679	.1361	.0347	.0990	.1029	.6406	.6406	.1161	88
3–2Ca	.2950	.1440	.0260	.0326	.0497	.5473	.5473	.0128	73
4–Mg	.3160	.1410	.0478	.0355	.0472	.5875	.5805	.0555	80
5–2Mg	.2723	.1628	.0432	.0564	.0494	.5841	.5841	.0596	80
6–M	.3039	.1053	.0428	.0065	.0772	.5357	.5868	.0223	73
7–M	.3388	.1204	.0571	.0531	.0704	.6398	.....	.....	88
8–O	.3285	.0854	.0478	.0508	.0564	.5689	.....	.....	78
9–Mg	.2487	.1364	.0532	.0452	.0899	.5734	.....	.....	78
10–MgCa	.2201	.1516	.0365	.0774	.0429	.5285	.5285	.0040	72
11–CaS	.3257	.0931	.0350	.....	.0480	.5018	.5018	0	69
12–2CaS	.3173	.1140	.0378	.....	.0412	.5103	.5103	0	70

TABLE 36. GRAMS POTASH FROM SOIL 2349.

	Sorghum 1911	Sorghum 1911	Corn 1912	Sorghum 1912	Corn 1913	Total.	Gain over 0.	Per million of soil.
1–O	.5359	.0660	.1795	.0254	.1245	.9313	.....	121
2–Ca	.2753	.0288	.3285	.1049	.1634	.9009	.....	116
3–2Ca	.1420	.0187	.4738	.1044	.1932	.9321	0	121
4–CaS	.4437	.0125	.1912	.....	.1322	.7796	0	101
5–2CaS	.3419	.0120	.2202	.0316	.1442	.7499	0	96
6–Mg	.3832	.1152	.2525	.0304	.1452	.9265	0	120
7–2Mg	.2121	.0336	.4239	.0882	.1068	.8646	0	112
8–Manure	.5917	.0257	.1809	.0623	.1470	1.0076	.0763	131

TABLE 37. RELATION OF PERCENTAGE OF POTASH IN CROP TO ACTIVE POTASH OF SOIL.

Laboratory Number.	Per cent Potash in crop.	Active Potash of soils per million.
First Crops.		
4649	.74	74
4583	.70	83
1956	.96	105
2353	.79	106
2349	1.74	113
4601	.96	118
4599	1.41	136
4579	.82	159
4642	1.47	169
1809	1.85	220

Laboratory Number.	Per cent Potash in crop.	Residual Active Potash per million.
Last Crops.		
4649	.52	36
4579	.31	43
4583	.43	48
4601	.12	49
2349	.30	49
4642	.32	58
4599	.35	60
1956	.59	78
1809	.45	91

TABLE 38. ACTIVE POTASH IN SOIL AT END OF EXPERIMENT, AND REMOVED BY CROPS—PARTS PER MILLION OF SOIL.

Laboratory Number.	No Addition		Carbonate of Lime	
	In soil.	Removed by crops.	In soil.	Removed by crops.
1290	59	54	54	62
1809	91	320	77	220
1956	78	122	74	139
4579	43	118	41	118
4583	48	62	41	65
4599	60	123	67	121
4642	58	152	61	159
4649	36	33	34	34
4601	49	66	49	88
2349	49	121	50	116

THE EFFECT OF CROPPING ON THE ACTIVE POTASH IN THE SOIL.

After the experiments were completed, the soils were brought to the laboratory for analysis. The results of some of the analyses are given in Tables 39-47.

The effect of the additions did not increase the active potash of the soil, remaining after the crops were gathered. In the case of carbonate of lime, this is summarized in Table 38. In every case, the quantity of active potash remaining at the end of the experiment was practically the same with or without carbonate of lime, excepting in Soil No. 1809, in which there appears to have been a greater loss of

potash than the analysis would show. According to these results, the addition of carbonate of lime did not have any effect upon the quantity of active potash in the soil remaining at the end of the experiment. This is in confirmation of what has previously been said; namely, that the addition of carbonate of lime had little effect upon the potash of the soil.

TABLE 39. LOSSES OF ACTIVE POTASH, PER MILLION OF SOIL 1290.

Additions to Original.	In soil.	Loss by soil.	Removed by crops.	Per cent lost by soil in per cent of that removed.
1-O	56.9	33	49	67
2-O	60.6	29	58	50
3-Cobs	74.4	26	70	37
4-Cobs	56.2	24	71	34
5-Ca	39.4	50	64	78
6-Ca	69.4	21	58	36
7-Saw	76.9	13	48	72
8-Saw	66.2	24	52	46
9-H	77.5	12	41	29
10-H	78.6	12	46	26
11-HCa	50.6	39	52	75
12-HCa	55.0	35	54	64
Average	63.5	27	55	48
Original soil	90			

TABLE 40. LOSSES OF ACTIVE POTASH PER MILLION OF SOILS 1908 AND 1956.

Additions to original.	1809				1956			
	In soil.	Loss by soil.	Removed by crops	Lost by soil in % of that removed	In soil.	Removed by crops.	Loss by soil.	Lost by soil in % of that removed
1-O	98.1	122	313	39	74.4	138	31	22
2-O	83.8	136	326	42	81.9	115	23	20
3-Ca	81.9	138	250	55	73.7	136	31	23
4-Ca	72.5	147	291	51	75.6	142	26	18
5-XCa	95.0	125	311	40	68.1	158	37	23
6-XCa	75.0	145	318	46	67.0	155	38	25
7-S	83.7	136	327	42	71.9	88	33	38
8-S	107.5	112	329	34	71.2	157	34	22
9-XS	110.0	110	312	25	111.3	102	0	0
10-XS	86.6	133	328	41	103.8	144	1	1
11-Na	103.8	116	325	36	92.5	140	12	9
12-Na	95.6	124	292	42	100.0	80	5	6
13-2 Na	106.9	113	287	39	90.0	129	15	12
14-2 Na	106.3	114	250	46	96.3	84	9	11
15-H	119.4	101	330	31	73.2	153	32	21
16-H	102.5	117	354	33	93.8	112	11	98
17-VH	85.6	134	307	44	77.5	120	27	22
18-VH	93.1	127	324	39	99.4	71	6	8
19-CaH	103.8	116	323	36	76.9	148	28	19
20-CaH	108.1	112	321	35	76.9	131	28	21
21-CaVH	106.3	114	302	38	82.5	143	22	15
22-CaVH	101.2	119	290	41	78.7	131	26	20
Average	92.1	123	310	40	83.5	126	22	21
Original soil	220				105			

TABLE 41. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4599.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	49.4	110	87	79
2–O	35.6	125	99	79
3–Ca	44.5	115	91	79
4–Ca	38.7	121	97	79
5–2Ca	36.2	115	100	87
6–2Ca	36.9	118	99	84
7–CaS	35.0	90	101	112
8–CaS	37.5	117	98	84
9–M	41.2	112	95	85
10–M	31.2	115	105	91
11–MCa	33.1	120	103	86
12–MCa	40.0	119	96	81
Average	38.3	115	98	86
Original soil	136			

TABLE 42. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4583.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	49.4	64	34	53
2–O	49.9	59	36	61
3–Ca	42.0	71	41	58
4–Ca	40.0	60	43	72
5–2Ca	35.6	57	46	81
6–CaS	62.2	57	21	37
7–M	44.4	63	39	62
8–M	41.3	63	42	67
9–MCa	31.2	67	52	78
Average	43.7	62	39	63
Original soil	83.0			

TABLE 43. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 2349.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	49.1	121	64	53
2–Ca	50.0	116	63	54
3–2Ca	62.9	121	50	41
4–CaS	56.3	101	57	56
5–2CaS	44.4	96	69	72
6–Mg	51.2	120	62	52
7–2Mg	56.3	112	57	51
8–Manure	51.3	131	62	47
Average	52.7	115	61	53
Original soil	113			

TABLE 44. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4642.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	60.6	153	108	71
2–O	56.9	151	112	74
3–Ca	64.2	156	105	67
4–Ca	58.1	162	111	69
5–2Ca	60.6	160	108	68
6–2Ca	56.9	160	102	64
7–CaS	47.5	153	121	79
8–CaS	68.0	157	101	64
9–M	59.6	166	109	66
10–M	61.2	166	108	65
11–MCa	61.2	155	108	70
12–MCa	10.8	162	108	67
Average	59.6	158	108	69
Original soil	169			

TABLE 45. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4579.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	60.0	128	99	77
2–O	60.6	119	98	82
3–Ca	70.6	126	81	64
4–Ca	63.7	117	95	82
5–2Ca	58.7	122	100	82
6–CaS	53.1	121	106	88
7–M	75.0	133	84	63
8–M	66.6	121	92	76
9–MCa	75.6	124	83	67
Average	64.9	123	93	76
Original soil	159.0			

TABLE 46. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4601.

Additions to original.	Parts per million.			Lost by soil in % of that removed.
	In soil.	Removed. by crops.	Loss by soil.	
1–O	51.2	66	66	100
2–Ca	47.5	88	70	80
3–2Ca	49.4	73	69	95
4–Mg	50.6	80	67	84
5–2Mg	49.4	80	69	86
6–M	63.8	73	54	74
7–M	72.5	88	45	51
8–O	46.9	78	71	91
9–Mg	50.0	78	68	87
10–MgCa	52.5	72	65	90
11–CaS	77.5	69	40	58
12–CaS	62.5	70	55	79
Average	56.2	76	62	81
Original soil	118			

TABLE 47. LOSSES OF ACTIVE POTASH PER MILLION OF SOIL 4649.

Additions to original.	Parts per million.			Lost by soil in % of that Removed.
	In soil.	Removed by crops.	Loss by soil.	
1-O	36.2	33	38	115
2-Ca	33.7	34	40	118
3-2Ca	33.7	30	40	133
4-CaS	40.0	29	34	117
5-2CaS	31.2	25	43	172
6-M	32.5	49	41	84
7-M2Ca	30.6	39	44	113
Average	34.0	34	40	122
Original soil	74			

In the experiments on Soils Nos. 1290, 1909, and 1956, the additions of sugar humus have apparently increased the active potash of the soil. This occurs with two of the three experiments. In the case of manure, however, in a subsequent experiment, there is no relation to be traced between the addition of manure and the amount of active potash. That is to say, the active potash apparently was not affected by the addition of manure.

Study of the tables brings out clearly the fact that carbonate of lime, sulphate of lime, and similar additions, have no such effect upon the quantity of potash removed by crops, as has been claimed by Huston, for example.

In Tables 39-47, inclusive, we have included the quantity of active potash in the soil at the end of the experiment, the quantity lost by the soil during the experiment, and the quantity removed by the crop. All this is stated in parts per million of the soil.

The quantities removed by the crops are, with only one or two exceptions, larger than those lost by the soil. We have expressed this relation in per cent. of the quantity taken up by the crop. Thus, with no addition, Soil No. 1290 contained 57 parts per million at the end of the experiment, and as the original content was 90, the quantity lost by the soil was 33. The crop, however, took up 49 parts per million, so that the potash lost by the soil is 67 per cent. of that taken up by the crop.

The quantity of active potash lost by the soil is less than the quantity taken up by the crop for two reasons.

In the first place, the active potash does not represent all the easily soluble potash, since subsequent extractions will remove additional quantities. Further, some of the active potash represents difficultly insoluble potash compounds. (See Bulletin 145 of this Station.)

In the second place, a portion of the potash taken up by plants comes from the insoluble potash. (Bulletin 145.)

Thus with a large amount of active potash in the soil, a great proportion of the potash taken up by the plant comes from it. Also the crop contains more potash, and the active potash rapidly decreases. The potash lost from the soil is thus a high percentage of that removed by the crop. This may be seen, for example, with Soil No. 4599, Table 41.

With a small amount of active potash in the soil, a larger proportion of the potash removed from the crop comes from the insoluble potash. The soil after continued cropping may lose practically all its active potash, and the potash taken up by the crops then comes from the insoluble potash compounds. This condition has probably been reached by most of the soils used in this experiment, and the quantity of active potash at the end of the experiment proabably represents, in most cases, the potash dissolved by the acid solvent from the insoluble potash.

PREPARATION OF SUGAR HUMUS.

As a quantity of sugar humus was needed in the work just described, and the literature available gave no description of the method to be used, we made some study of the method.

To ascertain the conditions which give the best yield of humus from sugar, the following experiments were undertaken. Varying conditions were studied as described below.

Three grams of commercial granulated sugar were used in every instance. The sugar with the desired amount of acid of the required strength was introduced into a 200 c.c. Erlenmeyer flask fitted with a reflux condenser and digested in a boiling water bath for the desired time.

Hydrochloric and sulphuric acids were used, as it is not desired to risk contamination of the humus by nitric acid. The different concentrations were made by dilution of a 10 per cent. solution prepared by titration.

After digestion, the humus was filtered on a weighed gooch, washed four times with water, and dried in a water oven to constant weight.

241A **TABLE 48. EFFECT OF TIME.**

Sugar Used.	Time of Digestion.	Volume of Acid.	Strength of Acid. (Per Cent.)	Per Cent of Humus.
3 grams	1 hour	50 c.c. HCl	10	3.55
3 grams	2 hours	50 c.c. HCl	10	5.49
3 grams	5 hours	50 c.c. HCl	10	6.12
3 grams	10 hours	50 c.c. HCl	10	7.18
3 grams	20 hours	50 c.c. HCl	10	8.40

241B **TABLE 49. STRENGTH OF ACID.**

Sugar Used.	Time of Digestion.	Volume of Acid.	Strength of Acid (Per Cent)	Per Cent of Humus.
3 grams	5 hours	50 c.c. HCl	1	0.37
3 grams	5 hours	50 c.c. HCl	5	3.86
3 grams	5 hours	50 c.c. H_2SO_4	5	1.52
3 grams	5 hours	50 c.c. HCl	10	6.30
3 grams	5 hours	50 c.c. HCl	Concentrated	30.40

241C TABLE 50. RATIO OF ACID TO SUGAR.

Sugar Used.	Time of Digestion.	Volume of Acid.	Strength of Acid. (Per Cent.)	Per Cent of Humus.
3 grams	5 hours	30 c.c. HCl	10	8.83
3 grams	5 hours	50 c.c. HCl	10	6.48
3 grams	5 hours	100 c.c. HCl	10	4.88
3 grams	5 hours	200 c.c. HCl	10	3.29

A supplementary experiment was made with concentrated hydrochloric acid in the same manner as 241A to test the effect of time of digestion for the formation of humus.

241A TABLE 51. EFFECT OF TIME.

Sugar Used.	Time of Digestion.	Volume of Acid.	Strength of Acid. (Per Cent.)	Per Cent of Humus.
3 grams	1 hour	50 c.c. HCl	Concentrated	28.70
3 grams	2 hours	50 c.c. HCl	Concentrated	28.05
3 grams	5 hours	50 c.c. HCl	Concentrated	28.88
3 grams	10 hours	50 c.c. HCl	Concentrated	30.07
3 grams	20 hours	50 c.c. HCl	Concentrated	39.74

The following method of preparation was adopted: Weigh 400 grams of sugar in a flask, add 2000 c.c. concentrated hydrochloric acid, and heat two hours in a boiling water bath. Then dilute with cold water, filter off, wash thoroughly, and dry.

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SUMMARY AND CONCLUSIONS.

1. These experiments were designed to ascertain the effect of carbonate of lime and other additions upon the potash removed by crops upon eleven soils during several years.

2. Gains of potash due to the addition of carbonate of lime or organic matter are comparatively small and probably come from the insoluble potash of the soil.

3. The active potash of the soil needs no addition of carbonate of lime, as it is already highly available.

4. Sulphate of soda and gypsum are often injurious.

5. Plants take up an excess of potash. The percentage of potash in the plants decreases as the amount of active potash in the soil decreases.

6. Additions of carbonate of lime did not increase the quantity of active potash remaining in the soil at the end of the experiments.

7. The quantity of active potash lost is 60 to 90 per cent. of that taken up by the crop, until the active potash is reduced so that the potash removed actually comes from insoluble potash compounds and not from the active potash.

8. Active potash may be readily and rapidly removed by crops down to the quantity representing the potash from highly insoluble compounds.

9. Additions of sulphate of lime, nitrate of soda, or other salts have no such effect upon rendering potash available to plants as has been claimed. They would have only a slight effect.

10. Conditions affecting the yield of sugar humus are studied, and a method for preparing it is described.