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W. B. BIZZELL, President

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DIVISION OF CHEMISTRY

AVAILABILITY OF POTASH IN SOME SOIL-FORMING MINERALS

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BULLETIN NO. 284. DECEMBER, 1921

AVAILABILITY OF POTASH IN SOME SOIL-FORMING MINERALS

BY

G. S. FRAPS.

A knowledge of the availability of potash in minerals which occur in the soil is important to soil chemistry. It aids in the interpretation of the analysis of the soil and in judging methods of analysis.

McCaughey and Fry (Bulletin 91 of the Bureau of Soils, U. S. Department of Agriculture) have found that four primary minerals in the soil are the chief carriers of potash. These are biotite, muscovite, orthoclase, and microcline. Potash may also occur in secondary minerals formed by weathering agencies upon primary minerals, and it may be absorbed and held by minerals in a loose form of combination.

In Bulletin 145 of this Station, it was shown that the potash of nephelite, leucite, glauconite, and biotite was completely dissolved when heated with hydrochloric acid of 1.115 sp. gr. With muscovite, 37 per cent. of the potash was dissolved. Two samples of microcline and four samples of orthoclase gave up 0 to 4 per cent. of their potash.

With fifth-normal nitric acid, practically no potash was removed from microcline and orthoclase. Less than 10 per cent. of the potash was removed from glauconite and biotite. From 15 to 60 per cent. of the potash was removed from muscovite, nephelite, leucite, apophyllite, and phillipsite.

It is of some importance to soil chemistry to know whether there is any relation between the solubility of these minerals in acid and the amount of potash that they will give up to plants.

Breazale and Briggs (Journal of Agricultural Research, 20, 615, 1921) find that the potash dissolved in water from finely ground orthoclase is not absorbed by wheat seedlings to a measurable degree, and that the availability of the potash is not increased by the addition of lime, gypsum, or carbon dioxide to the solution, or by boiling the solution. But if the solution from orthoclase is oxidized with hydrochloric and nitric acids, the potash becomes available. They ascribed this change to a breaking down of the complex solute molecules. The concentration of a plant-food element in the soil solution, they conclude, does not necessarily provide any measure of its availability, but the question of availability must be referred to the plant itself.

J. K. Plummer (Journal of Agricultural Research, 14, 298, 1918) reports a study of the availability of potash in soil-forming materials to certain crops when the potash was added to the soil at the rate of 400 to 800 parts per million, and gives a review of the literature. The percentages of potash removed from the minerals by the crops, calculated by us from the data given, are given in Table 1. The crops were grown in succession, and potash and lime were added only at the be-

ginning of the experiment. It is somewhat surprising to find 24 per cent. of the potash of orthoclase, 49 per cent of that of muscovite, and 56 per cent. of that of biotite, removed by four crops. It is also to be noted that increasing the amount of mineral potash decreased the percentages removed by crops.

Table 1. Percentages of potash removed from minerals.—Plummer.

	Oats	Soybean	Rye	Cowpea	Total 4 crops	Average per crop
Microcline	.9	1.7	1.1	.2	3.9	1.0
2 Microcline	.3	.8	0	0	1.1	.3
2 Microcline plus calcium carbonate	.4	1.7	0.1	0.6	2.8	.7
2 Microcline plus 2 calcium carbonate	.3	1.7	0	0.6	2.6	.7
Orthoclase	4.2	14.0	2.9	3.0	24.1	6.0
2 Orthoclase	2.9	7.6	1.4	1.5	13.4	3.4
2 Orthoclase plus calcium carbonate	2.0	9.4	1.5	3.4	16.3	4.1
2 Orthoclase plus 2 calcium carbonate	2.8	9.7	1.5	3.3	17.3	4.3
Muscovite	13.2	21.8	6.6	8.0	49.6	12.4
2 Muscovite	5.0	10.8	3.5	5.0	24.3	6.1
2 Muscovite plus calcium carbonate	5.0	14.6	3.3	6.3	29.2	7.3
2 Muscovite plus 2 calcium carbonate	4.9	13.6	3.5	6.5	28.5	7.1
Biotite	13.6	24.0	6.1	12.7	56.4	14.1
2 Biotite	6.5	9.9	4.1	6.1	26.6	6.7
2 Biotite plus calcium carbonate	6.5	18.2	4.2	8.1	37.0	9.3
2 Biotite plus 2 calcium carbonate	5.9	18.1	4.0	6.1	34.1	8.5
Potassium sulphate	17.0	22.7	7.2	15.1	62.0	15.5
2 Potassium sulphate	11.0	18.5	6.9	10.7	47.1	11.8
2 Potassium sulphate plus calcium carbonate	11.6	26.8	7.7	16.0	62.1	15.5
2 Patassium sulphate plus 2 calcium carbonate	11.4	30.5	7.8	17.0	66.7	16.7

De Turk (Soil Science, VIII, 1919, 219) presents a review of the literature on potassium-bearing minerals as a source of potassium for plant growth, together with pot experiments and laboratory work.

EXPERIMENTAL WORK.

The work here described was carried out in three separate series. In the first series, the amounts of potash added to the soil in the form of the soil minerals are comparatively small, equal to .25 gram of potash to 5000 grams soil or 500 parts per million of soil. In the second series of experiments, the amount of potash added in the mineral potash was much larger than in the first series or about 4000 parts potash per million of soil. Nitrogen and phosphoric acid were used in addition in each of these experiments. No potash was added after the first addition.

The third series of experiments was conducted to test the effect of granite as a fertilizer. At that time it was proposed to use granite alone as a fertilizer on Texas soils, and although our present knowledge showed that such a use would not be profitable, it was thought well to run a few pot tests to show the effect of granite as compared with the effect of other materials. This experiment is not really a test of the availability of the potash of granite, as no phosphoric acid or nitrogen was used in connection with the granite. A similar test already published by the Rhode Island Experiment Station showed that granite has little or no value as a fertilizer.

First series. Five kilograms of soil were weighed out as usual, potash added equal to 0.25 gm. or 500 parts per million, 1 gm. nitrate of soda and 2.5 gms. acid phosphate were added; also to one set of

soils, carbonate of lime was added in the form of precipitated chalk at the rate of 5 gms. to the pot, or 1000 parts per million. In another series sawdust was added at the rate of 25 gms. to the pot, or 5000 parts per million.

Second series. The soils were weighed out as follows: 7200 gms. of soil 4595, 7000 gms. of soil 4598, 8000 gms. of soil 4600, 7600 gms. of soil 4606, 6800 gms. of soil 4646, 7700 gms. of soil 4648. These soils received 20 gms. of microcline, or orthoclase, 10 gms. of biotite, muscovite, pinite, chabazite, or stilbite, in addition to 1 gm. of nitrate of ammonia and 1 gm. of acid phosphate. The first crop was sorghum, planted June 6 and harvested September 4. Nitrate of ammonia was added and sorghum planted again.

The third crop was corn, and the soil received 1 gm. of dicalcium phosphate and 1 gm. of ammonium nitrate. A fourth crop was grown on some of the soils, ammonium nitrate being added to these pots.

The potash removed from the soil which received no potash, was deducted in all cases, so that the figures given represent the potash removed from the mineral.

RESULTS.

Table 2 shows the grams potash removed from the soil to which 0.25 gm. potash was added, and the average per cent. removed. This varies from 1 per cent. microcline, No. 1177, to 38.7 per cent. with sulphate of potash.

Table 2. Grams potash recovered from 0.25 gram potash added to soil.

Laboratory Number		Microline 224	Microcline 1177	Microcline 1180	Orthoclase 1178	Biotite 1176	Muscovite 1179	Leucite 711	Nephelite 253	Sulphate of potash 1877
1269	Cotton	.0217	.0033	.0035	.0153	.0206	.0375	0	.0372	.0456
	Cotton, carbonate of lime added	.0081	0	.....	.0079	.0265	.0053	0	.....	.0485
	Cotton, sawdust added	0	.....	.....	.0153	0	.0128	0	.....	0
1592	Corn	.....	.....	.....	.....	.0547	.0477	0	.....	.1687
1585	Corn	.....	.....	.....	.....	.0595	.0534	.....	.....	.1880
1269	Millet	0	.0041	.....	0	.0366	.0085	0	0	.1294
	Average	.0075	.0025	.0035	.0096	.0330	.0275	0	.0186	.0967
	Average per cent removed	3.0	1.0	1.4	3.8	13.2	11.1	0	7.4	38.7

Table 3 shows the grams of potash removed by the crops in the second series of experiments. The largest recovery was usually made with the first crop, especially with sulphate of potash.

Table 3. Grams potash removed by crops second series.

		Microcline 1177	Orthoclase 1178	Biotite 2563	Muscrovite 2397	Pinite 1393	Sulphate 4562	Chabazite 2551	Stilbite 4646
4595	Crop 1, Sorghum	0	.0333	.1729	.1167	.0707	.3258	0	.....
	Crop 2, Corn	0	.0062	.1319	.0150	0	0	0	.....
	Crop 3 Sorghum	.0270	0	.2248	.0133	0	.0142	0	.....
	Total	.0270	.0392	.5296	.1450	.0707	.3400	0	.....
4598	Crop 1, Sorghum	0	.0083	.2177	.1723	0	.3873	.0080	.....
	Crop 2, Sorghum	0	0	.0370	.0277	0	.0060	0	.....
	Crop 3, Corn	.0217	.0003	.0380	.0183	.0048	.0694	.0141	.....
	Crop 4, Sorghum	.0050	.....	.0275	.....	.....	.0154	.0033	.....
	Total	.0267	.0086	.3202	.2183	.0048	.4781	.0254	.....
4600	Crop 1, Sorghum	.0067	0	.1528	.1155	.....	.3417	.....	.....
	Crop 2, Sorghum	.0029	.0078	.0571	.0233	.....	.0612	.....	.....
	Crop 3, Corn	.0031	0	.0056	.....	.....	0	.....	.....
	Total	.0127	.0078	.2155	.1388	.....	.4029	.....	.....
4606	Crop 1, Sorghum	.0394	.0821	.0168	0	.....	.0114	.....	.....
	Crop 2, Sorghum	.0089	0	.0488	.0805	.....	.0888	.....	.....
	Crop 3, Corn	.0163	.0457	.2377	.1030	.....	.1102	.....	.....
	Crop 4, Sorghum	.0490	0	.1079	.0357	.....	.0528	.....	.....
	Total	.1136	.1278	.4112	.2192	.....	.2632	.....	.....
4646	Crop 1, Sorghum	.0272	.0946	.1203	.1550	0	.4085	0	0
	Total	.0272	.0946	.1203	.1550	.....	.4085	.....	.....
4648	Crop 1, Sorghum	.0077	.0177	.1441	.1419	0	.3677	.0515	.0082
	Crop 2, Sorghum	.0153	.0232	.0945	.0308	.0246	.0644	.0273	.0147
	Crop 3, Corn	0	0	.0385	.0045	0	.0040	.0109	0
	Total	.0230	.0409	.2771	.1772	.0246	.4361	.0897	.0229
	Grams potash added	2.028	2.362	0.962	0.931	0.518	0.5504	0.100	.028

The amounts of potash added to the pots are shown at the bottom of the table. Smaller quantities of potash were added in biotite, muscovite, pinite, and sulphate of potash than in orthoclase and microcline, on account of the fact that the potash in the former is more easily taken up.

Table 4. Total percentage of potash removed by all crops second series.

Soil No.	Number of crops	4594 3	4598 4	4600 3	4606 4	4646 1	4648 3	Average 3
1177	Microcline	1.33	1.32	0.63	5.60	1.34	1.13	1.89
1178	Othoclase	1.67	0.36	0.33	5.41	4.01	1.73	2.25
1393	Pinite	13.65	0.93	.....	.....	0	4.75	4.83
2347	Muscovite	15.57	23.45	14.91	23.54	16.65	19.00	18.86
2563	Biotite	18.36	33.30	22.41	42.76	12.51	28.82	26.36
4646	Stilbite	.....	.....	.....	.....	0	81.78	40.89
2551	Chabazite	0	25.40	.....	.....	0	89.70	28.78
4563	Sulphate of potash	67.93	95.52	80.50	52.59	81.62	87.13	77.55

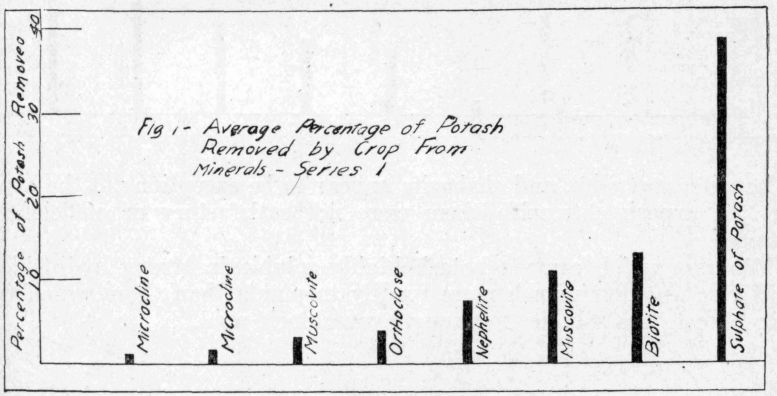
Table 4 shows the total percentages of added potash taken up by the crops averaging four in number. They are in the following order, beginning with the lowest: microcline, orthoclase, pinite, muscovite, biotite, stilbite, chabazite, sulphate of potash. The variation with stilbite and the chabazite is very wide in the individual tests.

Table 5 contains the average percentage of potash removed per crop in the second series of experiments. It consists of the percentages in Table 4 divided by the number of crops.

Table 5. Average percentage of mineral potash removed per crop second series.

		4594	4598	4600	4606	4646	4648	Average
1177	Microcline	0.45	0.33	0.21	1.40	1.34	0.38	.68
1178	Othoclase	0.56	0.36	0.33	1.35	4.01	0.58	1.19
1393	Pinite	4.55	0.24	.....	.....	0	1.58	1.59
2347	Muscovite	5.19	5.86	4.97	5.89	16.65	6.33	7.48
2563	Biotite	18.36	8.33	7.47	10.69	12.51	9.61	11.16
2552	Stilbite	.....	.....	.....	.....	0	27.26	13.63
2551	Chabazite	0	6.35	.....	.....	0	29.90	9.06
4563	Sulphate of potash	22.64	23.88	26.83	13.15	81.62	29.04	32.86

Table 6 shows the percentage of potash in the materials used, the per cent dissolved by fifth-normal nitric acid (Bulletin 145), and the percentages removed per crop in the experiments discussed in this bulletin. It also shows the relation between the potash dissolved by the fifth-normal acid and that taken up by the crops in the various series of experiments. If the experiments made by Plummer with larger quantities of minerals were cited, instead of these with smaller quantities, the percentages taken up from the minerals would be about one-half of that given, and probably more nearly related to that in the soil.

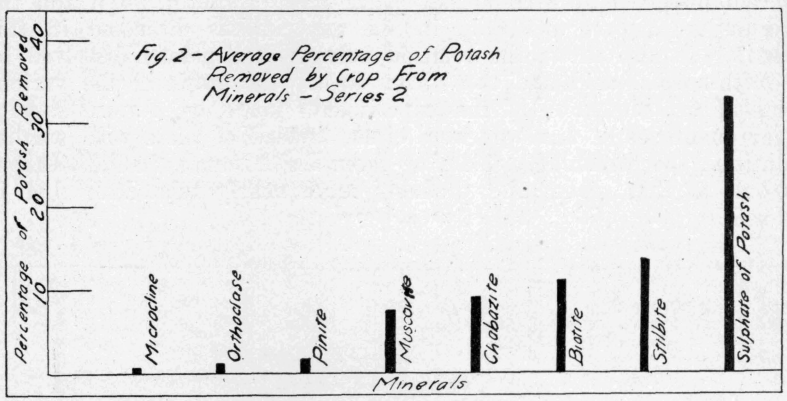


The amount of potash taken by one crop from microcline averages the same as the quantity dissolved by fifth-normal nitric acid. The relation for orthoclase varies from 1:1 to 5.5 times the quantity dissolved by the nitric acid. One crop removed from muscovite from 0.3 to 0.7 of that dissolved by fifth-normal nitric acid, from biotite 0.3 to 0.5, from stilbite 0.4, and from sulphate of potash 0.2, 0.3, 0.4. The relation decreases with the solubility of the potash mineral, but there is a relation between the potash removed by crops and the potash dissolved from the minerals by fifth-normal nitric acid.

The extraction of 7.5 to 12.4 per cent. of the potash per crop from muscovite, and 9.3 to 13.3 per cent. from biotite seems high. All the minerals used in our experiments were finely ground. It is probable that this affects their availability to crops, so that potash in the soil in these minerals would not be as available as was the case in these experiments. This would also affect the solubility in fifth-normal

nitric acid. Thus the solubility in fifth-normal nitric acid would represent the availability of potash in these minerals.

It would appear from the preceding discussion that the minerals containing high percentages of potash soluble in fifth-normal nitric acid give up their potash more readily to crops than those containing low percentages soluble in fifth-normal nitric acid. It would also appear that one crop of the plants took up potash about equal to that soluble in fifth-normal nitric acid from microcline and orthoclase, and about half of that dissolved from biotite, muscovite, or stilbite, and about four-tenths of that in sulphate of potash. Thus fifth-normal nitric acid is a measure of the available potash in these minerals.



Leucite, nephelite, and chabazite appear to be exceptions to the above, but the experiments with them were not satisfactory or sufficient in number.

Minerals which contain potash highly soluble in strong hydrochloric acid give up their potash more readily to plants than those which contain potash less soluble in strong hydrochloric acid.

Table 6. Relation of average potash removed by one crop to total and active potash of minerals.

	Microcline 1177	Microcline 180	Microcline 224	Orthoclase	Muscovite	Pinite	Biotite	Stilbite	Nephelite	Sulphate of Potash
Total potash, per cent	10.14	13.61	12.58	11.81	10.20	5.80	9.62	0.28	2.86	50.04
Per cent total potash soluble in N–5 nitric acid	0.9	1.3	1.6	1.1	17.1	5.4	26.4	34.0	49.3	100
Percentage total potash removed per crop (Plummer)	1.0	.....	.....	6.0	12.4	.....	6.7	.....	.....	11.8
Percentage total potash removed per crop, first series	1.0	1.0	3.0	3.8	11.1	.....	13.2	.....	7.4	38.7
Percentage total potash removed per crop, second series	0.7	.....	.....	1.2	7.5	1:6	11.2	13.6	.....	32.9
Percentage active potash removed per crop (Plummer)	110	.....	.....	550	71	.....	25	.....	.....	12
Percentage active potash removed per crop, first series	110	80	190	350	70	.....	52	.....	15	39
Percentage active potash removed per crop, second series	80	.....	.....	110	60	30	45	40	.....	33

EXPERIMENTS WITH GRANITE.

In these experiments, 5 kg. soil was used, nothing being added to pot No. 1, 5 gms. granite to Nos. 2 and 3, 1 gm. each of ammonia nitrate, dicalcium phosphate, and sulphate of potash to No. 4, 1 gm. each of ammonium nitrate and sulphate of potash to No. 5, 1 gm. each of dicalcium phosphate and sulphate of potash to No. 6. Corn was planted April 11 and harvested June 15. Ammonium nitrate or sulphate of potash was again added, and sorghum planted June 22 and harvested August 23. The granite contained 4.94 per cent. of total potash.

The result of this experiment is shown in Table 6, and Fig. 1 shows test on two of the soils with corn.

Table 7. Experiments with ground granite.—Grams per pot.

		Weight of Crop						O Grams potash	G Gram potash	G Gram potash	Potash in granite taken up
		None	Granite	Granite	Phosphoric acid potash nitrogen	Potash nitrogen	Phosphoric acid potash				
8841	Corn	5.4	5.5	6.5	25.7	7.2	7.4	.1355	.1540	.1606	.0218
	Sorghum	1.7	1.6	1.3	36.7	8.0	0.4	.0255	.0231	.0213	0
9140	Corn	5.6	6.4	4.7	30.1	3.5	10.2	.2363	.2304	.1936	0
	Sorghum	0.7	0.6	0.6	24.9	9.5	3.2	.0132	.0106	.0119	0
9166	Corn	3.1	3.2	2.9	23.5	2.7	11.2	.1159	.1120	.1354	.0117
	Sorghum	1.0	0.6	1.1	29.2	2.7	0.3	.0109	.0076	.0177	.0012
9300	Corn	6.9	7.4	8.3	42.4	13.0	11.7	.2146	.2338	.2224	.0135
	Sorghum	2.5	2.8	4.2	33.2	10.5	2.5	.0421	.0420	.0613	.0096

Table 8. Details of pot experiments.

		Gram crop	Per cent potash	Grams potash	Increase grams
1592	Series 3—1909 Corn.				
	Muscovite	37.0	.48	.1824	.0477
	Microcline	25.5	.55	.1347	.....
	L—	26.5	.46	.1219	0
	B—	37.1	.51	.1892	.0547
	K—	38.4	.79	.3034	.1687
1585	Series 3—1909 Corn.				
	1-0	10.6	1.50	0.1590	.....
	2-M	22.6	0.94	0.2124	.0534
	3-K	22.4	1.46	0.3470	.1880
	4-B	23.0	0.95	0.2185	.0595
1269	Series 18—Cotton.				
	Microcline—224	7.7	.84	.0646	.0217
		9.5	.76	.0722	.....
	Sulphate of potash	8.0	1.45	.120	.0456
		7.5	0.86	.0645	.....
	O	8.0	0.74	.0592	.....
	O	3.6	0.95	.0342	.....
	Biotite	6.9	.84	.0578	.0206
	Biotite	9.6	.80	.0768	.....
	Microcline—1177	6.3	0.80	.0504	.0033
	Microcline	5.9	0.84	.0496	.....
	Orthoclase—1178	5.6	0.80	.0448	.0153
	Orthoclase	9.9	0.80	.0792	.....
	Microcline—1180	5.7	0.82	.0467	.0035
	Microcline	7.9	0.68	.0537	.....
	Muscovite—1179	11.6	0.74	.0858	.0375
	Muscovite	9.3	0.78	.0725	.....
	Leucite—711	2.5	1.02	.0255	0
	Leucite	3.2	0.96	.0307	.....

Table 8. Details of pot experiments—Continued.

		Gram crop	Per cent potash	Grams potash	Increase grams
1268	Series 18—Cotton—Continued.				
	Nephelite--753	9.6	0.92	.0883	.0372
	Nephelite	9.7	0.82	.0795	
	Microcline—224	9.9	.82	.0811	.0081
	Microcline	8.0	.84	.0672	
	Sulphate of potash—1869	10.2	1.18	.120	.0485
	Sulphate of potash—1870	9.7	1.04	.109	
	O 1829	7.8	1.04	.0811	
	O 1870	5.0	1.02	.0510	
	Biotite	9.7	1.00	.097	.0265
	Biotite	8.0	1.10	.088	
	Microcline—1177	6.0	.94	.0564	0
	Microcline	7.0	.88	.0616	
	Orthoclase	7.2	1.10	.0792	.0079
	Orthoclase	6.6	1.04	.0686	
	Muscovite—1179	6.2	1.02	.0632	.0053
	Muscovite	7.5	1.06	.0795	
	Leucite—711	6.9	.74	.0511	0
	Leucite	3.0	.98	.0294	
	Microcline—224	7.2	1.04	.0749	0
	Microcline	7.9	.78	.0616	
	Sulphate of potash—1871	6.3	.95	.0598	0
	Sulphate of potash—1872	7.0	1.16	.812	
	O 1881	10.4	0.74	.0770	
	O 1882	9.9	.86	.0851	
	Biotite	7.9	.90	.0711	0
	Biotite	8.2	.88	.0721	
	Orthoclase—1178	10.5	.78	.0819	.0153
	Orthoclase	9.9	1.12	.1108	
	Muscovite—1179	13.1	.86	.1127	.0128
	Muscovite	8.5	.88	.0750	
	Leucite—711	5.7	.84	.0479	0
	Leucite	7.7	.86	.0662	
4595	Crop 1, Sorghum.				
	1-0	67.2	1.23	.8266	
	2 Microcline	57.0	1.45	.8265	0
	3 Orthoclase	63.7	1.35	.8599	.0333
	4 Biotite	62.7	1.61	1.0095	.1729
	5 Muscovite	59.7	1.58	.9433	.1167
	6 Pinite	68.5	1.31	.8973	.0707
	7 Sulphate of potash	70.7	1.63	1.1524	.3258
	8 Chabozite	62.7	1.24	.7775	0
	Crop 2, Sorghum.				
	1-0	25.3	.79	.1998	
	2 Microcline	23.4	.97	.2270	.0270
	3 Orthoclase	26.0	.76	.1976	0
	4 Biotite	29.9	1.42	.4246	.2248
	5 Muscovite	27.7	.77	.2133	.0133
	6 Pinite	28.5	.69	.1966	0
	7 Sulphate of potash	25.2	.85	.2142	.0142
	8 Chabozite	23.3	.80	.1864	0
	Crop 3, Corn.				
	1-0	37.3	.43	.1604	
	2 Microcline	35.4	.43	.1522	0
	3 Othoclase	34.7	.48	.1666	.0062
	4 Biotite	40.6	.72	.2923	.1319
	5 Muscovite	33.1	.53	.1754	.0150
	6 Pinite	29.8	.29	.0864	0
	7 Sulphate of potash	31.3	.44	.1377	0
	8 Chabozite	29.5	.46	.1357	0
4598	Crop 1, Sorghum.				
	1-0	36.5	.79	.2883	
	2 Microcline	29.7	.91	.2703	0
	3 Othoclase	33.7	.88	.2966	.0083
	4 Biotite	44.0	1.15	.5060	.2177
	5 Muscovite	34.0	1.09	.3706	.1723
	6 Pinite	39.2	.71	.2783	0
	7 Sulphate of potash	36.2	1.59	.5756	.3873
	8 Chabozite	35.7	.83	.2963	.0080
	Crop 2, Sorghum.				
	1-0	2.7	.77	.0208	0
	2 Microcline	2.5	.79	.0197	0
	3 Othoclase	2.7	.58	.0157	0
	4 Biotite	5.4	1.07	.0528	.0370
	5 Muscovite	5.0	.97	.0485	.0277
	6 Pinite	1.9	.88	.0167	0
	7 Sulphate of potash	2.6	1.03	.0268	.0060
	8 Chabozite	2.3	.74	.0170	0

Table 8. Details of pot experiments—Continued.

		Grams crop	Per cent potash in crop	Grams potash in crop	Grams potash removed
	Crop 3, Corn.				
	1–0	11.9	.45	.0535	.....
	2 Microcline	17.9	.42	.0752	.0217
	3 Orthoclase	11.7	.46	.0538	.0003
	4 Biotite	20.8	.44	.0915	.0380
	5 Muscovite	16.7	.43	.0718	.0183
	6 Pinite	11.9	.49	.0583	.0048
	7 Sulphate of potash	25.6	.48	.1229	.0694
	8 Chabozite	16.5	.41	.0676	.0141
4598	Crop 4, Sorghum.				
	1–0	1.8	.74	.0133	0
	2 Microcline	3.0	.61	.0183	.0050
	3 Orthoclase	0.1	.....	.....	.....
	4 Biotite	5.1	.80	.0408	.0275
	5 Muscovite	0.2	.....	.....	.....
	6 Pinite	0.8	.....	.....	.....
	7 Sulphate of potash	4.1	1.70	.0287	.0154
	8 Chabozite	2.6	.64	.0166	.0033
4600	Crop 1, Sorghum.				
	1–0	51.9	.70	.3633	.....
	2 Microcline	50.0	.74	.3700	.0067
	3 Orthoclase	50.5	.70	.3535	0
	4 Biotite	50.6	1.02	.51661	.1528
	5 Muscovite	50.4	.95	.4788	.1155
	6 Sulphate of potash	54.0	1.25	.6750	.3417
	Crop 2, Sorghum.				
	1–0	5.4	.47	.0254	.....
	2 Microcline	5.9	.48	.0283	.0029
	3 Othoclase	7.9	.42	.0332	.0078
	4 Biotite	15.0	.55	.0825	.0571
	5 Muscovite	12.5	.43	.0537	.0233
	6 Sulphate of potash	15.2	.57	.0866	.0612
	Crop 3, Corn.				
	1–0	4.0	.49	.0196	.....
	2 Microcline	4.2	.54	.0227	.0031
	3 Orthoclase	2.1	.69	.0145	0
	4 Biotite	10.5	.24	.0252	.0056
	5 Muscovite	.....	.....	.....	.....
	6 Sulphate of potash	1.0	.71	.0074	0
4606	Crop 1, Sorghum.				
	1–0	31.9	1.20	.3828	.....
	2 Microcline	36.4	1.16	.4222	.0394
	3 Orthoclase	36.9	1.26	.4649	.0821
	4 Biotite	29.6	1.35	.3996	.0168
	5 Muscovite	29.5	1.26	.3717	0
	6 Sulphate of potash	30.8	1.28	.3942	.0114
	Crop 2, Sorghum.				
	1–0	7.7	.91	.0701	0
	2 Microcline	7.9	1.00	.0790	.0089
	3 Othoclase	6.2	.89	.0552	0
	4 Biotite	8.2	1.45	.1189	.0488
	5 Muscovite	14.2	1.06	.1505	.0805
	6 Sulphate of potash	13.7	1.16	.1589	.0888
	Crop 3, Corn.				
	1–0	15.8	.61	.0364	0
	2 Microcline	19.1	.59	.1127	.0163
	3 Othoclase	20.6	.69	.1421	.0457
	4 Biotite	28.8	1.16	.3341	.2377
	5 Muscovite	27.7	.72	.1994	.1030
	6 Sulphate of potash	24.6	.84	.2066	.1102
	Crop 4, Sorghum.				
	1–0	7.5	1.02	.0765	0
	2 Microcline	14.1	.89	.1255	.0490
	3 Othoclase	9.1	.87	.0792	0
	4 Biotite	10.3	1.79	.1844	.1079
	5 Muscovite	12.2	.92	.1122	.0357
	6 Sulphate of potash	13.9	.93	.1293	.0538
4646	Crop 1, Sorghum.				
	1–0	46.5	.78	.3627	.....
	2–0	38.1	.96	.3658	.....
	3 Microcline	46.6	.84	.3914	.0272
	4 Othoclase	48.3	.95	.4588	.0946
	5 Biotite	29.6	1.51	.4470	.1203
	6 Biotite	46.6	1.12	.5219	.....
	7 Muscovite	44.0	1.18	.5192	.1550
	8 Pinite	33.4	1.02	.3407	0

Table 8. Details of pot experiments—Continued.

		Grams crop	Per cent potash in crop	Grams potash in crop	Grams potash removed
4646	Crop 1, Sorghum—Continued.				
	9 Sulphate of potash	47.7	1.62	.7727	.4085
	10 Chabozite	35.8	.92	.3294	0
	11 Stilbite	45.2	.92	.4158	.0516
	12 Pinite	41.4	.82	.3395	0
	Crop 2, Sorghum.				
	1–0	13.6	.....	.....	.....
	2–0	6.8	.....	.....	.....
	3 Microcline	4.4	.....	.....	.....
	4 Othoclase	5.7	.....	.....	.....
	5 Biotite	6.3	.....	.....	.....
	6 Biotite	12.1	.....	.....	.....
	7 Muscovite	6.4	.....	.....	.....
	8 Pinite	2.1	.....	.....	.....
	9 Sulphate of potash	3.2	.....	.....	.....
	10 Chabozite	11.2	.....	.....	.....
	11 Stilbite	16.3	.....	.....	.....
	12 Pinite	3.7	.....	.....	.....
4648	Crop 1, Sorghum.				
	1–0	42.2	.62	.2616	.....
	2–0	45.7	.61	.2788	.....
	3 Microcline	42.1	.66	.2779	.0077
	4 Othoclase	38.9	.74	.2879	.0177
	5 Biotite	43.3	.87	.3767	.1441
	6 Biotite	45.2	1.00	.4520	.....
	7 Muscovite	40.8	1.01	.4121	.1419
	8 Pinite	40.4	.66	.2666	0
	9 Sulphate of potash	47.2	1.38	.6514	.3677
	10 Chabozite	47.3	1.32	.6244	.....
	11 Stilbite	42.9	.75	.3217	.0515
	12 Pinite	33.2	.84	.2789	.0082
	Crop 2, Sorghum.				
	1–0	8.4	.37	.0311	.....
	2–0	7.4	.53	.0392	.....
	3 Microcline	13.3	.38	.0505	.0153
	4 Othoclase	12.2	.48	.0586	.0232
	5 Biotite	18.8	.69	.1297	.0945
	6 Biotite	3.8	1.18	0	.....
	7 Muscovite	15.2	.50	.0760	.0308
	8 Pinite	13.3	.45	.0598	.0246
	Sulphate of potash	15.3	.62	.0949	.0644
	10 Chabozite	15.8	.66	.1043	.....
	11 Stilbite	13.3	.47	.0625	.0273
	12 Pinite	8.6	.58	.0499	.0147
	Crop 3, Corn.				
	1–0	4.6	.29	.0133	.....
	2–0	5.7	.26	.0148	.....
	3 Microcline	4.3	.22	.0095	0
	4 Othoclase	3.2	.30	.0096	0
	5 Biotite	15.4	.27	.0416	.0385
	6 Biotite	15.9	.40	.0636	.....
	7 Muscovite	5.3	.35	.0186	.0045
	8 Pinite	1.6	.56	.0090	0
	9 Sulphate of potash	6.4	.29	.0186	.0040
	10 Chabozite	4.2	.42	.0176	.....
	11 Stilbite	7.8	.32	.0250	.0109
	12 Pinite	5.0	.27	.0135	0

As could be expected, the granite had little or no effect as a fertilizer. The potash in granite was dissolved only to a very slight extent. Similar results were secured by Hartwell and Pember, Rhode Island Experiment Station Bulletin 129.

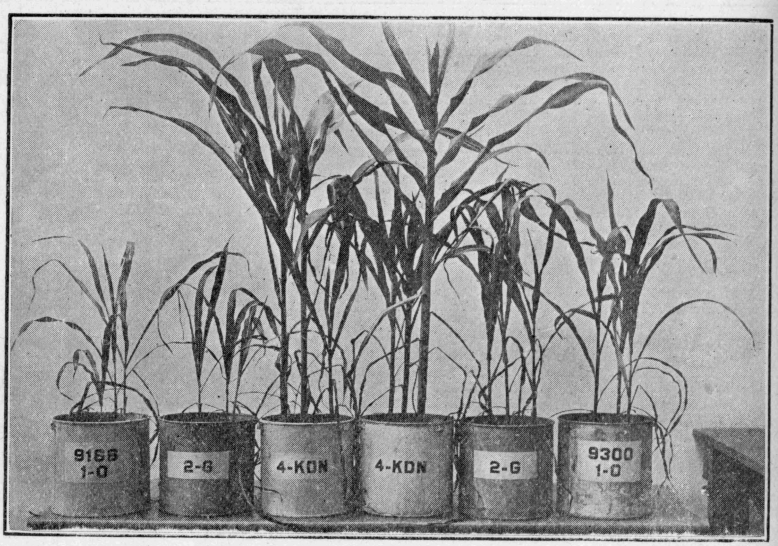


Fig. 3. Pot experiments on two soils with granite (2G) compared with no fertilizer (1-0) and complete fertilizer (4KDN).

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SUMMARY AND CONCLUSIONS.

1. The amounts of potash taken up by one crop from microcline average the same as the quantity dissolved by fifth-normal nitric acid. The amount taken up from orthoclase is somewhat more than that taken up by the acid.

2. One crop removed from muscovite on an average 30 to 70 per cent. of the potash dissolved by fifth-normal nitric acid, from biotite 30 to 50, from stilbite 40, from sulphate of potash 20, 30, 40 per cent.

3. There is a relation between the potash removed by crops and the potash dissolved from minerals by fifth-normal nitric acid.

4. The solubility of mineral potash in the soil in fifth-normal nitric acid would then be related to the potash removed by crops.

5. Minerals which contain potash easily soluble in strong hydrochloric acid give up their potash more readily to plants than those which contain potash less soluble in strong acid.

6. Granite has practically no value as a fertilizer.