AVAILABILITY OF POTASH IN CERTAIN ORTHOCLASE-BEARING SOILS AS AFFECTED BY LIME OR GYPSUM

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INTRODUCTION

Most soils appear to contain sufficient calcium to supply an abundance of that element so far as the actual food requirements of the crop are concerned. In the majority of cases in agricultural practice the application of lime, either as quicklime (CaO) or as the carbonate ($CaCO_3$), is made either on account of its effect upon the physical condition of the soil or to neutralize soil acids. There are cases, however, where a relatively small application of lime will accomplish beneficial effects that are not readily explainable on the basis of either of these postulates. The same is true with calcium sulphate, or gypsum ($CaSO_4.2H_2O$).

Such instances have perhaps helped to formulate the idea, apparently quite widely held, that calcium replaces potassium in the potash-bearing minerals of the soil, liberating this plant-food element. Thus, Hilgard,[1] in summarizing the important chemical effects of calcium carbonate, includes among others "the rendering available, directly or indirectly, of relatively small percentages of plant food, notably phosphoric acid and potash"; and again, in speaking of calcium sulphate, Hilgard makes the following statement:

Being soluble in 400 parts of water, it easily penetrates downward in most soils, and in doing so effects changes in the zeolitic portions, setting free potash from silicates and thus indirectly supplying plants with this essential ingredient in a soluble form. About 200 pounds per acre is an ordinary dose.[2]

Lyon, Fippin, and Buckman speak of the action of gypsum in liberating potassium, as "a property with which it has generally been credited" . . . "the actual extent of which has never been very clearly demonstrated."[3]

André[4] reports a greatly increased solubility of the potash in microcline in the presence of calcium carbonate or calcium sulphate, the solubility being 2 and 2.5 times, respectively, that in water alone.

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[1] Hilgard, E. W. Soils ... p. 379. New York, 1906.

[2] Hilgard, E. W. Op. cit., p. 43.

[3] Lyon, T. L., Fippin, E. O., and Buckman, H. O. Soils, their Properties and Management. p. 543. New York, 1915.

[4] André, G. Déplacement de la potasse contenue dans certaines roches feldspathiques par quelques substances employées comme engrais. *In* Compt. Rend. Acad. Sci. [Paris], t. 157, no. 19, p. 856-858. 1913.

Such reactions as may exist can not be considered to be independent of the character of the potash-bearing minerals in the soil. Prianischnikow [1] has shown with a number of different crops that marked differences exist in the availability of the potash in the various potash minerals, and that the availability corresponds approximately with the solubility of the potash of the different minerals in solutions of neutral salts. Of all the potash-bearing minerals tested, those of the feldspar group (orthoclase, microcline) showed the lowest available potash.

Blanck [2] has found that the potash in biotite and muscovite, minerals of the mica group, is more available to plants than that in orthoclase. The addition of finely ground microcline and orthoclase (equivalent to 1.6 gm. of potassium oxid) to sand (18 kgm.) having a very low potash content, resulted in little or no increase in the dry weight of oat plants, compared with plants grown in sand alone, and did not appreciably increase the potash content. An equal amount of potassium oxid applied as potassium sulphate increased the yield 70 per cent. Blanck concludes that the availability of the potash in potash-bearing minerals to plants increases proportionally to their sodium and calcium content.[3]

Many of the soils devoted to the culture of Citrus fruits in southern California have been derived from granite, pegmatite, or other rocks of this general type. Under the prevailing arid conditions the decomposition of the bedrock has been slow, and small lumps of granite, feldspar, and silica can still be found scattered plentifully through the soil.

Pegmatite and orthoclase were selected as types of the potash-bearing rocks and minerals that constitute the chief source of potassium in many of these Citrus soils. Samples collected near Riverside, Cal., were ground and passed through a 60-mesh sieve. Upon analysis by fusion, the pegmatite gave 1.50 per cent of potassium oxid and the orthoclase 12.56 per cent. The following experiments indicate that the addition of lime or gypsum to soils derived from orthoclase-bearing rocks has little or no effect, so far as the liberation of potash is concerned.

SOLUBILITY OF THE POTASSIUM IN PEGMATITE AS AFFECTED BY CALCIUM HYDRATE AND CALCIUM SULPHATE

Ten-gm. portions of pegmatite were weighed out and placed in shaker bottles with 1 liter of water, together with varying amounts of calcium hydrate (expressed as calcium oxid), as given in Table I. These mixtures

[1] Prianischnikow, D. Vegetationsversuche mit verschiedenen kalihaltigen Mineralien. *In* Landw. Vers. Stat., Bd. 77, Heft 5/6, p. 399-411, pl. 2-6. 1912.

[2] Blanck, E. Die Bedeutung des Kalis in den Feldspaten für die Pflanzen. *In* Jour. Landw., Bd. 61, Heft 1, p. 1-10. 1913.

[3] The solubility of the feldspar at temperatures above that of the soil is manifestly beyond the scope of this paper. Mention may appropriately be made, however, of a recent investigation by Stephenson, who has compared the action of various alkaline solutions on feldspars and hornblende at 100° C. and above. (Stephenson, E. A. Studies in hydrothermal alteration. Pt. I. The action of certain alkaline solutions on feldspars and hornblende. *In* Jour. Geol., v. 24, no. 12, p. 180-199, 8 fig. 1916.)

were shaken for 13 days and the clear solutions then analyzed for potash by the colorimetric method described by Cameron and Failyer.[1] The amounts of potash in these solutions is shown in Table I.

TABLE I.—*Effect of solutions of calcium hydroxid on the solubility of the potassium in pegmatite*

Solution No.	Calcium oxid in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1............................	0. 00	3. 1
2............................	. 0123	3. 1
3............................	. 0246	2. 5
4............................	. 0369	3. 1
5............................	. 0492	3. 0
6............................	. 0738	3. 0
7............................	. 0984	3. 1
8............................	a. 1230	2. 8

a Solid phase present.

The amount of potash recovered is so nearly uniform that these results could very well be considered to be multiplicate determinations of the potash content of the same solution.   There is no evidence that the lime liberated any potash from pegmatite.

Other 10-gm. portions of pegmatite were weighed out and placed in shaker bottles. To each portion was added 1 liter of distilled water, with varying amounts of calcium sulphate, as shown in Table II.   These mixtures were shaken for six days and the solutions then analyzed for potash.   The amounts of potash found in solution are given in Table II.

TABLE II.—*Effect of solutions of calcium sulphate on the solubility of potash in pegmatite*

Solution No.	Calcium sulphate in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1..................................	0. 00	2. 7
2..................................	. 0221	2. 1
3..................................	. 0446	2. 1
4..................................	. 0668	2. 0
5..................................	. 0864	3. 2
6..................................	. 1330	2. 2
7..................................	. 1660	2. 1
8..................................	a. 2100	2. 8

a Solid phase present.

As in the case of the calcium-hydrate solutions, there is no indication that the presence of calcium sulphate led to any replacement of the potash in pegmatite by lime.

[1] Cameron, F. K., and Failyer, G. H. The determination of small amounts of potassium in aqueous solutions. *In* Jour. Amer. Chem. Soc., v. 25, no. 10, p. 1063-1073. 1903.

SOLUBILITY OF THE POTASSIUM IN ORTHOCLASE AS AFFECTED BY
CALCIUM HYDRATE AND CALCIUM SULPHATE

Measurements relating to the effect of calcium hydrate on the solubility of potash in orthoclase, carried out in a similar manner to those with pegmatite, are given in Table III. Here, again, there is no indication that the presence of calcium affects the solubility of the potash.

TABLE III.—*Effect of solutions of calcium hydrate on the solubility of the potash in orthoclase*

Solution No.	Calcium oxid in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1	0. 00	10. 8
2	. 0103	8. 6
3	. 0207	12. 0
4	. 0414	8. 2
5	. 0621	9. 1
6	. 0828	12. 6
7	. 1035	12. 1
8	[a] . 1242	9. 6

[a] Solid phase present.

The results of similar determinations of the solubility of the potassium in orthoclase in the presence of solutions of calcium sulphate of varying concentration are presented in Table IV. A different sample of orthoclase was used in this case from that employed in the calcium hydroxid series, which accounts for the difference in solubility of the feldspar in distilled water in the two series. As before, there is no indication that potash is being replaced by lime. On the other hand, the results indicate that increasing the concentration of the calcium sulphate depresses the solubility of the potash.

TABLE IV.—*Effect of solutions of calcium sulphate on the solubility of the potash in orthoclase*

Solution No.	Calcium sulphate in 100 c. c. of solution.	Potassium oxid in solution.
1	0. 00	6. 0
2	. 018	4. 5
3	. 035	3. 6
4	. 070	3. 6
5	. 105	1. 2
6	. 140	. 8
7	. 175	1. 3
8	[a] . 210	. 5

[a] Solid phase present.

SOLUBILITY OF THE POTASH IN SOILS OF THE RIVERSIDE AREA AS INFLUENCED BY CALCIUM HYDRATE AND CALCIUM SULPHATE

A large sample of virgin soil from the site of the new University of California Citrus Experiment Station at Riverside was collected, dried in the sun, and passed through a 1-mm. sieve. Portions of this soil of 100 gm. each were weighed out and 500 c. c. of distilled water added, together with varying amounts of calcium hydroxid, as shown in Table V. The mixtures were shaken until the solutions had reached equilibrium. The amounts of potash found in the solutions are given in Table V. As in the case of the pegmatite and orthoclase experiments, the addition of calcium hydroxid does not modify the solubility of the potash in this soil sufficiently to be detected in the analyses.

TABLE V.—*Effect of solutions of calcium hydrate on the solubility of the potash in soil from the Citrus Experiment Station site*

Solution No.	Calcium oxid in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1.................................	0. 00	26. 4
2.................................	. 0103	26. 4
3.................................	. 0207	28. 8
4.................................	. 0414	28. 8
5.................................	. 0621	24. 0
6.................................	. 0828	27. 6
7.................................	. 1035	25. 2
8.................................	*a*. 1242	27. 6

a Solid phase present.

The solubility of the potash in the soil from the Citrus Experiment Station site in the presence of varying amounts of calcium sulphate was also determined. The concentration of the calcium-sulphate solutions and the amount of potash found in solution are given in Table VI.

TABLE VI.—*Effects of solutions of calcium sulphate on the solubility of the potash in soil from the Citrus Experiment Station site*

Solution No.	Calcium sulphate in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1.................................	0. 00	24
2.................................	. 017	24
3.................................	. 034	26
4.................................	. 068	29
5.................................	. 102	26
6.................................	. 136	26
7.................................	. 170	29
8.................................	*a*. 210	26

a Solid phase present.

The average variation (1 part in 25) in the potash content is well within the experimental error, when the lack of uniformity in the soil and the analytical difficulties are considered. There is no evidence that the addition of calcium sulphate modified to a measurable degree the solubility of the potash in this soil.

Another soil from the Oatman tract, about 7 miles from Riverside, was treated with calcium-sulphate solutions in the same way. This soil, which had been under cultivation for a number of years, was more granitic in character and less weathered than the virgin soil. The potash solubility in varying concentrations of calcium sulphate is shown in Table VII. Here, again, there is no indication of any replacement of potash by the lime; but, on the contrary, the addition of calcium sulphate depresses the solubility of the potash, as was found in the case of orthoclase (Table IV).

TABLE VII.—*Effect of solutions of calcium sulphate on the solubility of potash in Oatman soil*

Solution No.	Calcium sulphate in 100 c. c. of solution.	Potassium oxid in solution.
	Gm.	*P. p. m.*
1	0. 00	8. 6
2	. 017	8. 6
3	. 034	8. 0
4	. 068	4. 2
5	. 102	2. 2
6	. 136	2. 2
7	. 170	2. 4
8	[a]. 210	4. 2

[a] Solid phase present.

LeClerc and Breazeale[1] have shown that the sprouting seedling of wheat manifests a strong demand for potash, entirely out of proportion to its demand for nitrogen and phosphoric acid. When potash is present in a readily available form, the young wheat seedlings, during the first three weeks of growth, will often take up an amount of potash (K_2O) equivalent to 8 per cent or more of their dry weight. This avidity of the plant for potash was made use of in the following manner: Wheat seeds were sprouted on perforated aluminum disks floating in large pans. Each pan contained about 1,000 seeds. When the shoots had reached a length of about 2 cm., the plants were taken up, a few at a time, and transplanted to other disks, floating in the various solutions listed in Table VIII. In this way all the unsprouted seeds were eliminated, which would otherwise have become a source of potash. The solutions in the pans were stirred frequently and the plants were

[1] LeClerc, J. A., and Breazeale, J. F. Translocation of plant food and elaboration of organic plant material in wheat seedlings. U. S. Dept. Agr. Bur. Chem., Bul. 138, 32 p., 2 fig. 1911.

allowed to grow for varying periods, ranging from 5 to 12 days. Plant samples were then withdrawn and analyzed for potash by the official method. Table VIII shows the treatment and the percentage of potassium oxid in each lot of plants, expressed in terms of the dry weight.

TABLE VIII.—*Potash absorbed by wheat seedlings from orthoclase and soil solutions as affected by calcium sulphate.*

Series No.	Treatment.	Percentage of potassium oxid in dry plants.
1	10 gm. of orthoclase, 2,500 c. c. of carbon-treated water	1. 10
1	Same, saturated with calcium sulphate	.95
2	10 gm. of orthoclase, 2,500 c. c. of carbon-treated water	1. 84
2	Same, saturated with calcium sulphate	1. 72
3	40 gm. of orthoclase, 2,400 c. c. of carbon-treated water plus 200 p. p. m. NO$_3$ and 200 p. p. m. P$_2$O$_5$	2. 56
3	Same, saturated with calcium sulphate	2. 57
4	50 gm. of Oatman soil, 2,500 c. c. of carbon-treated water	1. 75
4	Same, saturated with calcium sulphate	1. 35

The period of growth was varied so that the dry weight of the plants in the different series was not the same, which accounts for the differences in the potash content of the various cultures when expressed in percentage of the dry weight. In the third series 200 p. p. m. of NO$_3$ as NaNO$_3$ and 200 p. p. m. of P$_2$O$_5$ as Na$_2$HPO$_4$ were added to balance the nutrient solution.

To insure the solution of the potash, the solutions containing finely ground orthoclase in series 3 were shaken up for four days before they were used for culture purposes. Analyses of the resulting solutions at the time the cultures were started showed 9.6 p. p. m. of potassium oxid where gypsum was absent and 6 p. p. m. where gypsum was present. Such potash concentrations are sufficient for the nutrition of plants, as the potash content of the soil solution in humid soils seldom exceeds 10 p. p. m. It will be shown in another paper that wheat plants can readily take up potash and other salts in concentrations of 1 p. p. m. or less.

If the calcium sulphate had liberated any additional potash from the feldspar, the seedling plants would have taken it up, and this would have been shown by an increase of the potash content of the plant ash. In none of the three series of cultures, however, was the potash content of the plants increased by the addition of gypsum to the solution.

In the Oatman soil (series 4) the addition of gypsum decreased the absorption of potash by plants. It will be recalled that the analyses of the solutions also showed that the use of gypsum depressed the solubility of the potash in this soil (Table VII).

SUMMARY

It is stated in agricultural treatises that the application of lime to a soil liberates potash from the soil minerals. This subject is of special import to the Citrus industry of southern California in which commercial fertilizers are extensively used and heavy applications of lime and gypsum are sometimes made.

Samples of pegmatite and orthoclase were collected near Riverside, Cal., representing, respectively, types of the potash-bearing rock and mineral from which many of the Citrus soils appear to be derived. These samples were finely ground and shaken for a number of days with aqueous solutions of calcium hydroxid and of calcium sulphate in graduated concentrations. The calcium-hydrate solutions did not modify the solubility of the potassium in either pegmatite or orthoclase. Gypsum solutions depressed the solubility of the potassium in orthoclase, the quantity of potash in solution decreasing progressively as the concentration of the calcium sulphate increased.

Similar tests were made upon a virgin soil of a granitic type from the experiment station near Riverside, Cal. The solubility of the potash was not measurably different in distilled water and in solutions of calcium hydrate or calcium sulphate.

The addition of calcium sulphate to a Citrus soil which had been under cultivation for some time and which was more granular and less weathered than the virgin soil, decreased the solubility of the potash.

The potassium content of wheat seedlings was practically the same when grown (1) in water containing finely ground orthoclase and (2) in a saturated calcium-sulphate solution containing the same quantity of orthoclase.

Similar experiments in which a Citrus soil was used instead of orthoclase showed a decreased absorption of potassium by wheat seedlings in the presence of calcium sulphate.

In brief, the experiments indicate that the availability to plants of the potash in soils derived from orthoclase-bearing rocks is not increased by the addition of lime or gypsum. In some instances a marked depression of the solubility of the potash in the presence of gypsum was observed. These conclusions are based both on the results of the analyses of the solutions and on the measurement of the potash content of wheat seedlings grown in the solutions.