CONCENTRATION OF POTASSIUM IN ORTHOCLASE SOLUTIONS NOT A MEASURE OF ITS AVAILABILITY TO WHEAT SEEDLINGS

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The object of the experiments described in this paper was to determine the availability of the potassium in solution of orthoclase by growing wheat seedlings in aqueous orthoclase solutions, analyzing the seedlings for potassium, and comparing the results with those obtained from suitable controls. The results show that the potassium present in solutions of orthoclase is not appreciably absorbed by young wheat plants. The conclusion is reached that potassium may be present in soil solutions in such combination with other elements that it is not available to plants.

The orthoclase used in our experiments was obtained near Riverside, Calif., and contained a total of 12.5 per cent of potassium oxid (K_2O). It was ground to pass a 60-mesh sieve. Different samples when brought into equilibrium with water and analyzed[1] contained from 2 to 9 parts per million of soluble potassium, the saturation concentration not being definite. There was, however, always some potassium present in the aqueous solutions, the average concentration being about 4 parts of potassium oxid per million of solvent.

The wheat was germinated on perforated aluminum disks floated on water. When the plumules were about ½ inch long the seedlings were transferred to other aluminum disks in the pans containing the culture solutions. This early transfer prevents the young seedling plants from absorbing the potash which exudes form unsprouted seeds.

The method of experimentation was, in general, to compare the potassium content of wheat seedlings grown in orthoclase solutions with that of similar seedlings grown in distilled water or other suitable control solution free from potassium.

SOLUBLE POTASSIUM IN ORTHOCLASE NOT AVAILABLE TO WHEAT SEEDLINGS

Wheat cultures were grown in orthoclase solution with and without the addition of gypsum and were compared with cultures grown in distilled water alone and in distilled water to which gypsum had been added. (See Table I, series a.) Although the orthoclase solutions were known

[1] The J. Lawrence Smith method was used in the analysis.

from analyses to contain potassium, it will be noted that the wheat seedlings were unable to absorb any of it. This is of special interest, since the avidity of wheat seedlings for potassium is very marked.

The culture solutions in series b, Table I, included a control of distilled water (No. 1), 40 gm. of finely ground orthoclase in 2,500 cc. of distilled water (No. 3), and potassium chlorid solution containing 4 parts per million of potassium oxid (No. 5). Culture solutions Nos. 2, 4, and 6 were similar to No. 1, 3, and 5, respectively, except that gypsum was added to each in excess, so that it would always be present in the solid phase. To each of the six cultures were added also 50 parts per million of nitrate (NO_3) as sodium nitrate and 50 parts per million of phosphoric acid (P_2O_5) as sodium phosphate. Each solution, except those in which orthoclase was present in the solid phase, was changed twice daily in order to insure uniformity in concentration and freedom from bacterial disturbances. The wheat seedlings were grown in these culture solutions for 10 days. The analyses of the plants indicated, as before, that the wheat seedlings were unable to remove potassium from the orthoclase solutions. This was not due, however, to the diluteness of the solution, for in culture solutions containing only 4 parts per million of potash as potassium chlorid the plants were able to more than double their potash content in 10 days. The addition of nitrogen and phosphoric acid to the solutions did not modify the nonavailability of the potassium in the orthoclase solutions.

In series c the cultures were maintained for 17 days, all solutions being changed daily. Nitrogen and phosphoric acid were added to one culture, the sodium base being omitted. The results again showed no marked absorption of potassium from the orthoclase solutions.

The plants in series d were grown for 15 days. The analyses, as in the preceding experiments, showed no appreciable absorption of potassium by plants grown in orthoclase solutions, but a marked absorption was observed by plants grown in solutions of potassium chlorid. The presence of gypsum or orthoclase in the potassium chlorid solutions did not modify the rate of absorption of potassium from these solutions by the wheat seedlings.

The results in Table I, taken as a whole, show that the potassium in orthoclase solutions is not absorbed in measurable quantity by the wheat seedlings. On the other hand, potassium in potassium-chlorid solutions of equivalent concentration is readily absorbed by the plants.

TABLE I.—*Relative availability of potassium in orthoclase solutions and in potassium-chlorid solutions*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1a	Control (distilled water).........	0	1.51	0.0295	0
2a	Control with $CaSo_4$.............	0	1.53	.0281	− 4
3a	Orthoclase (solid phase present).	2 to 9	1.54	.0284	− 3
4a	Orthoclase with $CaSo_4$ (solid phases present)..............	2 to 9	1.58	.0272	− 13
1b	Control.......................	0	1.36	.0365	0
2b	Control with $CaSo_4$.............	0	1.34	.0368	+ 1
3b	Orthoclase (solid phase present).	2 to 9	1.43	.0366	0
4b	Orthoclase with $CaSo_4$ (solid phases present)..............	2 to 9	1.45	.0372	+ 2
5b	K Cl.........................	4	1.50	.0783	+114
6b	K Cl with $CaSo_4$...............	4	1.40	.0860	+136
1c	Control.......................	0	3.68	.0310	0
2c	Orthoclase (solid phase present).	2 to 9	3.96	.0302	− 2
3c	Orthoclase with $CaSo_4$ (solid phases present)..............	2 to 9	3.68	.0345	+ 11
4c	Orthoclase with $CaCO_3$ (solid phases present)..............	2 to 9	3.92	.0341	+ 10
5c	Orthoclase with 50 p. p. m. NO_3 and 50 p. p. m. P_2O_5.....	2 to 9	3.64	.0341	+ 10
1d	Control.......................	0	4.08	.0368	0
2d	Control with $CaSo_4$.............	0	4.48	.0395	+ 7
3d	Orthoclase (solid phase present), changed daily................	2 to 9	4.30	.0457	+ 33
4d	Orthoclase and $CaSo_4$ (solid phases present), changed daily........................	2 to 9	4.50	.0411	+ 11
5d	Orthoclase (solid phase) and 4 p. p. m. K_2O as KCl, changed daily........................	6 to 13	4.50	.0978	+166
6d	KCl..........................	4	4.45	.0947	+157
7d	KCl with $CaSo_4$...............	4	4.85	.1010	+175
8d	Orthoclase and KCl, changed once.........................	6 to 13	4.20	.0683	+ 86
9d	Orthoclase, not changed.........	2 to 9	4.10	.0388	+ 5

AVAILABILITY OF POTASSIUM IN ORTHOCLASE SOLUTIONS NOT INCREASED BY LIME OR GYPSUM

The application of lime and gypsum to orthoclase-bearing soils has been considered by some workers as a means of increasing the availability of the potassium in such soils. The authors[1] found in an earlier investigation that the addition of lime or gypsum to orthoclase solutions containing the solid phase did not increase the concentration of the potassium in the solution. The data presented in Table I show that these substances also had no effect on the availability of the potassium in the orthoclase solution.

[1] BRIGGS, Lyman J., and BREAZEALE, J. F. AVAILABILITY OF POTASH IN CERTAIN ORTHOCLASE-BEARING SOILS AS AFFECTED BY LIME OR GYPSUM. *In* Jour. Agr. Research, v. 8, no. 1, p. 21–28. 1917.

AVAILABILITY OF THE POTASSIUM IN ORTHOCLASE SOLUTIONS NOT INCREASED BY BOILING THE SOLUTION

The effect of boiling an orthoclase solution on the subsequent availability of the potassium is shown in Table II. In this experiment the potassium content of the plants grown in the culture solution was compared with that of the original seed. The analyses show that within the errors of experiment the availability of the potassium was not modified by boiling the orthoclase solutions.

TABLE II.—*Effect of boiling orthoclase solutions on the availability of the soluble potassium*

Culture No.	Material analyzed.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1	Original seed	....	....	0.0368	0
2	Seedlings grown in orthoclase solution (solid phase present).	2 to 9	4.00	.0386	+5
3	Seedlings grown in orthoclase solution (solid phase present), boiled.	2 to 9	4.28	.0330	−8

AVAILABILITY OF POTASSIUM IN ORTHOCLASE SOLUTION NOT INCREASED BY PRESENCE OF CARBON DIOXID

Carbon dioxid is universally present in the soil solution. It is consequently desirable to determine whether the availability of the potassium in orthoclase may be measurably increased by the addition of carbon dioxid to the solution. A culture solution of orthoclase with the solid phase present was accordingly prepared, and a portion of this solution was saturated with carbon dioxid. Plants grown in the two solutions showed no difference in their potash content (Table III). It consequently appears that a weak acid, such as carbonic acid, in concentrations equivalent to those found in soil solutions, does not increase the availability of the potassium in orthoclase.

TABLE III.—*Effect of carbon dioxid on availability of potassium in orthoclase*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1	Orthoclase (solid phase present).	2 to 9	1.92	0.0284	0
2	Orthoclase (solid phase present) saturated with CO_2.	2 to 9	1.72	.0284	0

SOLUBLE POTASSIUM IN ORTHOCLASE SOLUTIONS IS MADE AVAILABLE BY OXIDATION WITH ACIDS

To determine whether the soluble potassium in orthoclase could be available by oxidation with acids, the following experiment was carried out.

Finely ground orthoclase was added to about 100 liters of water, and this mixture was shaken at intervals until equilibrium was established and the maximum solubility of the potassium in the feldspar had been obtained.

One-half of this solution was filtered through a padded folded paper filter, and the clear solution, together with a few cubic centimeters of a mixture of hydrochloric and nitric acids, was then evaporated to dryness in Jena beakers. The excess of acids was driven off, and the solution was brought back to volume with purified distilled water. A little calcium carbonate ($CaCO_3$) was then added to insure alkalinity. Wheat seedlings were grown in such cultures for 14 days, the solutions being changed daily. The results are given in Table IV, series a.

TABLE IV.—*Effect of oxidation of soluble potassium in orthoclase on its availability*

Culture No.	Culture solution.	K_2O in solution.	Dry weight of plants.	K_2O in 100 plants.	K_2O increase over control.
		P. p. m.	*Gm.*	*Gm.*	*Per cent.*
1a	Control	0	2.42	0.0326	0
2a	Orthoclase (solid phase present)	2 to 9	2.52	.0349	+7
3a	Orthoclase solution filtered and evaporated with acids	4	2.88	.0722	+121
4a	KCl	5	2.48	.0620	+90
1b	Control	0	3.30	.0203	0
2b	Orthoclase (solid phase present)	2 to 9	2.66	.0180	+11
3b	Orthoclase solution filtered and evaporated with acids	4	3.30	.0357	+76
4b	KCl	5	3.36	.0815	....

The wheat seedlings grown in orthoclase solutions in which the potassium compounds had been oxidized showed a total potash content at the end of the experiment about twice that of the plants grown in distilled water. On the other hand, the plants grown in the untreated orthoclase solution showed as before no gain in potash over the control.

A repetition of the experiment, Table IV, series 6, again showed a marked increase in the potash content of the plants grown in the solutions prepared from the oxidized solute. The orthoclase solution used in this series of experiments had stood in contact with the powdered mineral for about 2 months, being shaken at frequent intervals. The experiment extended over 19 days, the culture solutions being changed daily.

It is of interest to note that in the first series of experiments the potassium absorbed from the oxidized solute was equal to that absorbed from a potassium-chlorid solution containing 5 parts per million of potassium oxid. In the second series, the plants grown in the potassium-chlorid solution showed relatively a marked increase in their potassium content.

INCREASED AVAILABILITY OF POTASH IN OXIDIZED ORTHOCLASE SOLUTIONS NOT DUE TO ACTION OF ACIDS ON SUSPENDED COLLOIDS

The orthoclase solutions used in the preceding experiments contained some suspended colloidal material. It is therefore possible that the observed increase in the availbility of the potassium may have resulted from the direct action of the acids on the suspended colloids. To determine this point, a saturated solution of orthoclase was prepared and filtered through a Pasteur-Chamberland tube. A part of this filtrate was then treated with acids and evaporated to dryness, as described above, and subsequently diluted to its original volume and used as a culture solution. A portion of the original orthoclase solution which had not received the acid treatment was used as a control. The results of two experiments, made at different times, are given in Table V.

TABLE V.—*Effect of freeing culture solutions from colloids*

Culture No.	Culture solution.	K_2O in 100 plants.	K_2O increase over control.
		Gm.	*Per cent.*
1a....	Orthoclase solution, untreated with acids.............	0.0272	0
2a....	Orthoclase solution, treated with acids.................	.0597	+120
1b....	Orthoclase solution, untreated with acids.............	.0302	0
2b....	Orthoclase solution, treated with acids.................	.0551	+83

The analyses of the plants show as before a marked gain in the potassium content of the plants grown in the acid-treated solutions. The colloids can not in this case be considered the source of the potash made available by the acid treatment, since the colloidal material was removed from the solution before the acids were added. We are consequently led to conclude that the orthoclase solutions contain potassium in true solution (as distinguished from colloidal suspension) and that the potassium is chemically combined in such a manner that it is not available to plants.

DISCUSSION

The failure of wheat seedlings to absorb the potassium found by analysis in orthoclase solutions suggests that the potassium is combined with other elements in a slightly soluble molecular complex. This is supported by the fact that the potassium may be made available by treatment with strong acids, which would result from the breaking down of the complex. We may also assume that the solute complex is not dissociated, at least in such a way as to liberate potassium ions. For we can say with some assurance that free potassium ions would be absorbed by the wheat seedlings. We have evidence of this in the selective absorption exercised by wheat seedlings on potassium-chlorid solutions in which the potassium (either as $\overset{+}{K}$ or $\overset{+}{K}\overset{-}{OH}$) is selectively absorbed to such an extent that the culture solution becomes distinctly acid.

The effect of the oxidation of the solute complex in orthoclase solutions by hydrochloric and nitric acids is to reduce the potassium in the complex to potassium chlorid or potassium nitrate (KNO_3), in which form it dissociates and is readily absorbed.

The evidence presented in the case of orthoclase leads to the general statement that the concentration of a specific plant food element in the soil solution does not necessarily provide any measure of its availability. The question of availability must be referred to the plant itself, except perhaps in those cases in which the element in question is known to be ionized.

The results of our experiments have an immediate bearing on various investigations now in progress looking toward the utilization of orthoclase as a source of potash. It should be borne in mind that the application of finely ground orthoclase, without other treatment, probably does not contribute immediately to the available potash content of the soil.

CONCLUSIONS

From the experimental data presented the following conclusions are drawn, subject to the limitations imposed by the experimental error:

(1) The soluble potassium in aqueous solutions derived from finely ground orthoclase is not absorbed by wheat seedlings to a measurable degree.

(2) The availability of the potassium is not increased by the addition of lime, gypsum, or carbon dioxid to the solutions or by boiling the solutions.

(3) The soluble potassium in orthoclase solutions is made available by oxidizing the solute with hydrochloric and nitric acids.

(4) The increase in the availability following oxidation is not due to the action of the acids on suspended colloids, but is to be ascribed to the breaking down of the complex solute molecule.

(5) The concentration of a specific plant food element in the soil solution does not necessarily provide any measure of its availability. The question of availability must be referred to the plant itself.