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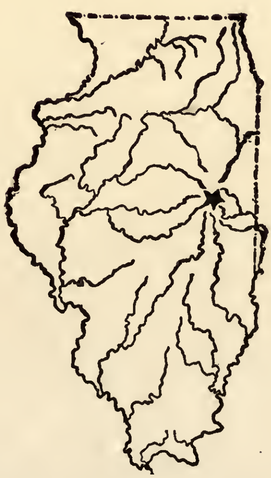
POTASSIUM FROM THE SOIL

By CYRIL G. HOPKINS and J. P. AUMER



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Summary of Bulletin No. 182

1. Potassium can be liberated as needed from the inexhaustible supply naturally contained in the normal soils of Illinois.

2. The amount of potassium taken up from ordinary Illinois soil by clover is from two to three times the amount required for plant growth. The excess probably is merely tolerated, as is sodium and silicon, both of which are present in the soil solution and are taken up by plants in considerable amounts, altho neither is essential for plant growth.

POTASSIUM FROM THE SOIL

By CYRIL G. HOPKINS, Chief in Agronomy and Chemistry, and
J. P. AUMER, Associate in Chemistry

Potash is so widely advertised and commercial potassium has been given such a prominent place in most of the experiments relating to soil fertility, both in this country and abroad, that the greatest natural source of potassium,—the soil,—like the inexhaustible atmospheric supply of nitrogen, is not generally understood or appreciated.

The fact is that the total amount of commercial potassium applied annually to all the farms of the United States is no more than is contained in one square mile of common corn-belt land to a depth of six feet, and the important potash problem is how to liberate it as needed from the inexhaustible supply already contained in all normal soils.

COMMERCIAL POTASSIUM

Potassium (also called kalium—K) is an important plant-food element. It makes up 83 percent of potash (K_2O), about 42 percent of commercial potassium chlorid (KCl), incorrectly called "muriate of potash," about 42 percent of commercial potassium sulfate (K_2SO_4), and about 10 percent of kainit, a crude salt taken directly from the German potash mines.

In the *Journal of Industrial and Engineering Chemistry,* January, 1915, page 59, Mr. W. H. Bowker, President of the Bowker Fertilizer Company, a branch of the American Agricultural Chemical Company, makes the following statement:

> "There are 7,000,000 tons of fertilizer consumed in this country annually, of which probably 5,000,000 tons are what are called complete fertilizers, that is, containing the three essential elements of plant nutrition—nitrogen, phosphorus, and potash."

It may be added that the most common so-called "complete" fertilizer used in this country contains about 1⅔ percent of potassium, while the most common corn-belt soil contains about 1¾ percent of potassium.

In the same article, Mr. Bowker quotes the following statement concerning the German Kali Works, or Potash Syndicate:

> "The Syndicate is spending a million dollars a year in its world-wide campaign, * * * * and any farmer who cares to study the statistics showing the enor-

mously increased use of potash in American fertilizers during the past decade must be convinced that advertising pays.''

NORMAL AND ABNORMAL SOILS

While some abnormal soils, such as the peat, or muck, of certain Illinois swamp lands and the siliceous sands of the Atlantic and Gulf Coastal Plains, are positively deficient in potassium, the most common, or normal, soils are richly supplied. (Normal soils are those which bear relation in composition to the average of the earth's crust from which they are formed.) Thus 2 million pounds of the common corn-belt land, corresponding to the plowed soil of an acre to a depth of about 6⅔ inches, contains about 35,000 pounds of potassium and 1,200 pounds of phosphorus, while 2 million pounds of the earth's crust contains as an average about 50,000 pounds of potassium and 2,200 of phosphorus.

While phosphorus is usually deficient, all must admit the abundance of potassium when the total supply of normal soils is considered; but the contention is usually made that the potassium of the soil is unavailable, and, instead of being advised to make it available, the farmer is urged to purchase soluble potassium salts from commercial agents.

THE ''INSOLUBLE RESIDUE''

The chief purpose of the investigations reported in this bulletin was to secure information as to the power of decaying organic matter to liberate potassium from the soil's abundant supply.

The method of soil analysis commonly employed by many investigators involves the digestion of a certain amount (10 grams) of the soil with a certain quantity (100 cubic centimeters) of a certain acid (hydrochloric) of a certain strength (specific gravity 1.115), at a certain temperature (the boiling point of water), for a certain time (10 hours). The ''insoluble residue'' is then discarded as valueless, and analyses are made of only that part of the soil which dissolves under these specific conditions arbitrarily fixed.

As shown by the many soil analyses reported in Bulletin 123, the ''acid-soluble'' potassium found by this method is, as a general average, only about 15 to 25 percent of the total potassium contained in the soil. It has seemed highly desirable, therefore, to ascertain whether growing plants with their roots in constant contact for months with the soil particles might not secure some potassium even from this ''insoluble residue,'' especially in connection with the decomposition products of organic matter. In other words, Can the plant find value in the ''insoluble residue'' discarded by the analyst?

PREPARATION OF POT CULTURES

This investigation was begun in 1909. The soil was taken from the Experiment Station Farm of the University of Illinois, which is representative of the brown silt loam of the early Wisconsin glaciation, the most common Illinois prairie land. This soil was found to contain 1.784 percent of total potassium, corresponding to 35,680 pounds in 2 million pounds of soil, but of this, an amount corresponding to 28,560 pounds remained in the "insoluble residue" by the common method of analysis just described.

By digesting many portions of this soil with the usual proportion and strength of acid under regular conditions of temperature and time, a sufficient quantity of the "insoluble residue" was secured for a series of pot cultures prepared as follows in glass jars of about one-gallon capacity.

Pots 1 and 1a were filled with normal soil.

Pots 2, 3, and 4 were filled with the "insoluble residue" from the acid-digestion of the same kind of soil, and the following chemicals in powdered form were incorporated with the "insoluble residue":

Pot 2. 120 grams of calcium carbonate, $CaCO_3$
120 grams of calcium phosphate, $Ca_3(PO_4)_2$
30 grams of calcium sulfate, $CaSO_4$
5½ grams of magnesium sulfate, $MgSO_4$
5 grams of iron chlorid, $FeCl_3$

Pot 3. The same as to Pot 2, and in solution .160 gram of ammonium nitrate, NH_4NO_3

Pot 4. The same as to Pot 2, and in solution .143 gram of ammonium nitrate, NH_4NO_3, and .089 gram of sodium ammonium phosphate, $NaNH_4HPO_44H_2O$

EXPERIMENTS AND RESULTS FOR 1910 AND 1911

Seven seeds of red clover (inoculated) and seven of rape were planted in each pot. The germination of the clover was poor, and the plants in the residue pots (2, 3, and 4) soon died. After about two weeks the rape plants were turned under.

To Pot 2 was then added .200 gram of potassium sulfate, K_2SO_4, and small amounts of ammonium nitrate and sodium ammonium phosphate. Rape and clover seed were again planted in all the pots several times, but in the extracted soil the plants failed to live, even in Pot 2, and further small applications of the plant-food solutions did not keep them alive. The plants in the normal soil were removed and seed replanted whenever the other pots were replanted.

The extracted soil was so compact and "run together" that the failure was clearly due to bad physical condition. To remedy this, a quantity of quartz sand was extracted by the usual method of acid-digestion described above, and a sufficient amount was mixed with the extracted soil of each pot to fill two pots. These extra pots were numbered 2a, 3a, and 4a. The soil of each of these six pots was then leached, or extracted, with distilled water, to remove at least part of the small amounts of soluble potassium, phosphorus, and nitrogen salts that might have remained from the previous applications.

Five clover seeds, inoculated with clover bacteria, were then planted in each pot, 2 of red clover and 3 of alsike. With some replanting, an irregular stand of alsike was finally secured, but the plants which survived showed very marked differences, or individuality, in their ability to develop. At the close of the season of 1910 the highest yield of dry matter from the tops and roots of the plants grown in the extracted soil where no potassium fertilizer had been added (Pot 4a) amounted to 6½ grams. From analyses of subsequent crops this dry matter was estimated to contain 22½ milligrams of potassium, while the total potassium added to this pot (in seed, inoculation, and impurities) had been only 1.4 milligrams. The smallest yield was in Pot 3a, in which none of the plants developed much growth. The crop of ½ gram from this pot was estimated to contain only twice as much potassium as the total additions.

Both tops and roots of the 1910 crop were incorporated with the extracted soil in the respective pots, and clover (chiefly alsike) was grown again in 1911. A perfect stand was not secured, but the plants grew very much better than in 1910. The clover tops were harvested on August 9, and again on December 21, when the roots were also removed, air-dried, and weighed.

The more important data for the two years are recorded in Table 1.

TABLE 1.—POTASSIUM APPLIED AND CLOVER PRODUCED IN POT CULTURES WITH INSOLUBLE RESIDUE FROM SOIL, 1910, 1911

(Expressed in grams)

Pot No.	Data for 1910		Data for 1911	
	Potassium applied	Dry produce	Potassium applied	Air-dry produce
1	.0024	No record	.00005	32.76
1a	.0022	8.0506	.00006	26.73
2	.3155	1.7768	.00004	30.33
2a	.3155	2.8305	.00007	18.79
3	.0013	1.4146	.00006	18.88
3a	.0013	.5094	.00010	13.08
4	.0015	1.6135	.00009	11.33
4a	.0014	6.5951	.00007	21.29

Aside from Nos. 2 and 2a, no pots received any potassium except that contained in the seed planted, in the inoculating material, and as impurity in the other plant foods used; and to Pots 2 and 2a potassium fertilizer was added only for 1910. The different plants grown in 1911 also showed considerable individuality, some making much better growth than others. The tops and roots were again incorporated as organic manure with the extracted soil in the respective pots.

EXPERIMENTS AND RESULTS FOR 1912

In 1912 two more pots were added to the series, Nos. 5 and 5a. These were filled with extracted[1] quartz sand. The same plant-food materials were added to these pots as were originally applied in powdered form to Pots 2, 3, and 4, but quartz contains no potassium, and thus differs from the ''insoluble residue'' from soil extraction.

The entire series was planted on February 12, 1912, with five seeds of alsike to each pot; and with some replanting a good stand was secured. The growth was fairly normal during the season. The leaves were gathered from time to time as they seemed to mature, and all were added to the final harvest on December 12, 1912, the produce from each pot being kept by itself. Figs. 1 and 2 show photographic views of these duplicated series of pot cultures with the 1912 clover crop.

The sand pots, 5 and 5a, were planted and replanted several times, and the solutions of ammonium nitrate and sodium ammonium phosphate were also added, but the plants either remained very small or finally died, neither pot producing sufficient crop to harvest or analyze.

The 1912 clover tops from all but the sand pots were analyzed, and likewise the roots from Pots 1a, 2a, 3a, and 4a; but the roots from Pots 1, 2, 3, and 4 were cut up and returned to those respective pots before planting the next crop. In Table 2 are recorded the important data concerning the 1912 crop.

TABLE 2.—POTASSIUM APPLIED, AIR-DRY CLOVER PRODUCED, AND POTASSIUM FOUND IN TOPS AND ROOTS ANALYZED, 1912

(Expressed in grams)

Pot No.	Potassium applied	Air-dry produce		Potassium found	
		Tops	Roots	In tops	In roots
1	.00003	25.56	14.29	.2852	.....
1a	.00003	34.20	12.04	.3310	.1109
2	.00003	34.20	16.30	.1487	.....
2a	.00003	41.07	26.80	.1519	.0257
3	.00004	34.40	13.40	.1406	.....
3a	.00003	29.08	10.47	.1206	.0215
4	.00005	25.25	13.70	.0909	.....
4a	.00007	38.51	17.30	.1324	.0232

With no addition of potassium fertilizer, the ''insoluble residue'' in Pots 3, 3a, 4, and 4a produced a larger average yield (31.81 grams)

[1]For this extraction dilute sulfuric acid was used.

FIG. 1.—CLOVER, 1912. POTS 1 TO 5 FROM LEFT TO RIGHT

in 1912 than was produced from the normal soil (29.88 grams, average of Pots 1 and 1a).

The total potassium added to Pots 3, 3a, 4, and 4a in seed, inoculation, and impurities amounted to 6 milligrams for the three years 1910-1912, while the amount of potassium found in the 1912 tops and roots analyzed from these four pots was 529.2 milligrams, of which 523.2 milligrams, or nearly 99 percent, must have been secured from the "insoluble residue."

The pots used were about 6 inches in diameter, and the total area of the four pots was not more than one fifty-thousandth part of an acre, so that potassium was secured from the "insoluble residue" at the rate of 26,160 grams, or 57 pounds, per acre. The air-dry hay harvested in 1912 from these four pots amounted to 127.24 grams, or to about 7 tons per acre, while the yield from the normal soil was about 6½ tons per acre.

The results indicate that after two years of green manuring, sufficient potassium was liberated from the "insoluble residue" to enable the clover to be benefited by the lime and phosphate fertilizers so as to outyield the crops on the normal soil, to which no such fertilizers had been applied.

The clover hay produced on the normal soil contained about three times as much potassium per gram as was contained in crops from the "insoluble residue," which indicates that the actual requirement for potassium by clover may be very much less than has been estimated from the composition of hay grown on ordinary soils. In other words, much of the potassium commonly found in crops may not be required but merely tolerated, being taken up by the growing plants because of the abundance in the soil.

Thus the facts established by these investigations tend to support the suggestion made in Bulletin 123 (page 216) and in the Appendix

FIG. 2.—CLOVER, 1912. POTS 1A TO 5A FROM LEFT TO RIGHT

of the County Soil Reports (under "The Potassium Problem"), that the benefit sometimes produced by potash fertilizers, when applied to soils very deficient in decaying organic matter, may be due in part at least to the power of the soluble potash salt to increase the availability of phosphorus or other elements.

EXPERIMENTS AND RESULTS FOR 1913 AND 1914

As already stated, the only organic matter incorporated with the soil in preparing for the 1913 planting was the clover roots in Pots 1, 2, 3, and 4, and the same plan was followed for 1914; that is, the tops from all pots and the roots from 1a, 2a, 3a, and 4a of the 1913 and 1914 crops were used for analysis, the same as in 1912. The important data for 1913 and 1914 are combined in Table 3.

TABLE 3.—POTASSIUM APPLIED, AIR-DRY CLOVER PRODUCED, AND POTASSIUM FOUND IN TOPS AND ROOTS ANALYZED, 1913 AND 1914

(Expressed in grams)

Pot No.	Potassium applied	Air-dry produce		Potassium found	
		Tops	Roots	In tops	In roots
1	.00012	67.73	4.81[1]	.8758	.....
1a	.00015	78.29	9.82[1]	.7849	.0404
2	.00016	51.05	15.23	.1979	.....
2a	.00019	33.38	6.66	.2526	.0159
3	.00020	50.99	24.80	.1960	.....
3a	.00021	16.84	3.90	.1390	.0071
4	.00012	76.33	25.22	.2909	.....
4a	.00018	43.82	12.72	.2083	.0158

[1]The roots in the normal soil (Pots 1 and 1a) were found largely decayed at harvest time and could be only partially saved for analysis.

The drainage outlet from Pot 3a became clogged, which probably accounts for the very poor growth, but it was apparent in both 1913 and 1914 that the clover grew better where the roots from previous crops were incorporated with the "insoluble residue." However, the authors have no explanation for the larger amount of potassium recovered from Pot 2a than from 2, unless it was the irregularity of subsequent leaching of the potassium applied to those pots in 1910. The total potassium secured from Pots 3, 3a, 4, and 4a for the two years 1913 and 1914 was 857.1 milligrams, or 428.5 milligrams per year, as compared with 529.2 milligrams for 1912.

POTASSIUM IN THREE CROPS

The potassium secured in the clover tops from Pots 3 and 4 was as follows:

231.5	milligrams in 1912
255.3	milligrams in 1913
231.6	milligrams in 1914
718.4	milligrams in three years

The total amount of potassium added to Pots 3 and 4 from 1910 to 1914 was 3.4 milligrams, so that 715 milligrams were secured from the "insoluble residue" by the clover tops analyzed from those two pots, where the roots were turned back each year. This corresponds to 158 pounds of potassium per acre in three years' crops. A 100-bushel crop of corn contains about 73 pounds of potassium in the grain, stalks, and cobs.

It seems plainly evident that potassium need not be purchased for use on normal soils for the production of the staple farm crops, but that it may easily be liberated in abundance by means of decaying organic matter, such as green manures, crop residues, and farm manures; and, of course, these materials, if applied in sufficient quantity, will supply nitrogen and liberate phosphorus from the phosphates naturally contained in the soil or applied to it where needed.