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BY

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SOME SOURCES OF POTASSIUM

BY C. T. HIRST and E. G. CARTER.

Foods Required by Plants.

The essential elements of plant food are ten in number. Of these carbon and oxygen are obtained by the plant from the air, and hydrogen from the water. Sulphur, calcium, iron and magnesium are required by plants in small quantities and are not likely to be deficient in soils. The three remaining ones—nitrogen, phosphorus, and potassium—are likely to be present in soils in smaller quantities and are used by plants in larger amounts than any of the other elements taken from the soil. In addition to these ten elements already named, five other elements, viz., silicon, aluminum, sodium, chlorine, and manganese are commonly present in plants, but these latter five are generally not considered to be essential to plant growth. In the soils of arid regions nitrogen is very low, while phosphorus and potassium are usually present in larger quantities.

Need of Potassium.

Potassium is essential to the plant either for photosynthesis or translocation. This is especially true in starch and sugar-producing plants such as potatoes and beets, for a deficiency in the potassium supply in the soil in which such crops are grown is shown by decreased amounts of starch and sugar produced. Next to sugar-producing plants legumes seem to be most dependent on potassium. A lack of potassium salts results in the production of shrunken grains, and very often it is found that these grains are sterile. It is also found that an insufficiency of potash salts causes plants to be more susceptible to disease and such plants are the first to succumb in unfavorable seasons. It seems also true that cell division does not proceed normally when there is a deficiency of potassium salts. As already stated, there are larger quantities of potassium salts present in most arid American soils than of the nitrogen and phosphorus, but in many soils there is not sufficient to supply the needs of plants.

1 Russel, "Soil Conditions and Plant Growth," p. 41.
In these cases potassium obtained from other sources must be added. This condition causes us to inquire as to the source of the potassium salts of commerce.

**German Potassium Deposits.**

Since about the middle of the last century the Stassfurt deposits of Germany have been the chief source of commercial potassium salts. "The Stassfurt salt and potash deposits had their origin thousands of years ago, in a sea or ocean, the waters of which gradually receded leaving near the coast lakes which still retained communication with the great ocean by means of small channels. In that part of Europe the climate was then tropical, and the waters of these lakes rapidly evaporated, but were constantly replenished through these small channels connecting them with the main body. Decade after decade this continued, until by evaporation and crystallization the various salts present in the seawater were deposited in solid form. The less soluble material such as sulphate of lime or 'anhydrite' solidified first and formed the lowest stratum. Then came common rock salt, with a slowly thickening layer which ultimately reached 3000 feet and is estimated to have been 13,000 years in formation. This rock salt deposit is interspersed with lamellar deposits of anhydrite, which gradually diminish towards the top and are finally replaced by the mineral 'polyhalit.' This mineral is composed of sulphate of lime, sulphate of potash and sulphate of magnesia. The location in which this polyhalit predominates is called the 'polyhalit region', and after it comes the 'kieserit region', in which between the rock salt strata kieserite, (sulphate of magnesia) is embedded. Above the kieserit lies the 'potash region' consisting mainly of deposits of carnallit, a mineral compound of chlorides of potash and magnesia. The carnallit deposit is from 50 to 130 feet thick and yields the most important of the crude potash salts, and that from which are manufactured most of the concentrated articles, including muriate of potash.

"Overlying this region is a layer of impervious clay, which acts as a water-tight roof to protect and preserve the very soluble potash and magnesia salts, which, had it not been for the protection of this overlying stratum, would have been long ages ago
washed away and lost by the action of the water percolating from above. Above this clay roof is a stratum of varying thickness of anhydrite, and still above this is a second salt deposit, probably formed under more recent climatic and atmospheric influences or possibly by chemical changes resulting in dissolving and subsequent precipitation of the compounds. This salt deposit contains 98 per cent or more of pure salt, a degree of purity rarely elsewhere found. Finally, above this are strata of gypsum, tenacious clay, sand, and limestone, which crop out at the surface.

"The perpendicular distance from the lowest to the upper surface of the Stassfurt salt deposits is about 5,000 feet (a little less than a mile), while the horizontal extent of the bed is from the Hartz Mountains to the Elbe River in one direction, and from the City of Magdeburg to the town of Bernburg in the other.

"These deposits, which have for many years been almost the sole source of potash in fertilizers, were first known as mines of rock salt. In 1839, having previously been acquired by the Prussian Treasury, they were abandoned by reason of the more economical working of rock salt quarries in other localities. It was determined thereafter to explore the extent of these mines by boring, and a well was sunk to the depth of 246 meters (807 feet) when the upper layer of the salt deposit was reached. The boring was continued into the salt to a total depth of 581 meters (1742 feet) without reaching the bottom. The results of these experiments were totally unexpected. Instead of getting a brine saturated with common salt, one was obtained containing large quantities of potassium and magnesium chloride. Shafts were sunk in other places, and with such favorable results that in 1862 potash salts became a regular article of commerce from that locality. At first these salts were regarded as troublesome impurities in the brine from which common salt was to be made, but at this time the common salt has come to be regarded as the disturbing factor. At the present time the entire produce is controlled by a syndicate of nine large firms located at Stassfurt and vicinity."1

1 Potash, published by the German Kali Syndicate, 1906.
United States a Large Consumer.

In 1911 the United States purchased nearly one-fifth of the potassium salts produced at Stassfurt and more than one-half of that exported from Germany. During the year ending June 30, 1911, the United States imported 1,109,549 tons of salts of potassium valued at $12,587,462.²

The fact that the German deposits have supplied the world with potassium for more than half a century does not mean that there are no potassium deposits in our country, for such is not the case. We have very large deposits of potash feldspars and micas, of leucite, alunite, etc., all containing potassium, but these substances are insoluble in water and up to the present time the expense attached to converting the potassium contained in most of these substances into an available form, has prohibited their use as a source of potassium.

Due to the European war the quantity of potassium salts imported into the United States in 1915 was only about one-tenth of that imported in 1913, the last normal year.¹ This has greatly increased of the price, and this increased value has given a great impetus to the search for potassium salts in this country.

Alunite and Other Mineral Sources.

Alunite, which is a natural potassium aluminum sulphate, occurs extensively in Colorado, Arizona, Nevada, California and Utah. At the present time the latter deposit seems to be the largest and best. In its natural state this mineral is insoluble in water, but by gentle heat it is rendered soluble and after leaching with water the solution is evaporated to dryness and ordinary alum is obtained. At higher and long continued heating sulphur trioxide is evolved and lexivigation of the roasted mass then yields a very pure potassium sulphate.² The Mineral Products Company, located at Marysvale, Utah, is turning out daily about one hundred tons of potassium sulphate extracted from this source.³

Efforts are being made to discover a process whereby the potassium of leucite may be rendered commercially available. During the last year the brine of a salt lake in Nebraska has yield-

² Fertilizer Resources of the United States, 1911, p. 28.
¹ Commercial Fertilizer, June 1916.
² Fertilizer Resources of the U. S. 1911, page 39.
³ Commercial Fertilizer, June 1916.
ed a considerable amount of potassium salts.\textsuperscript{4} Cave deposits have been located in various places in the west, as for example, those near Pocatello, Idaho, and in Greenwich Canyon near Koosharem, Utah. In 1902, companies were formed to develop deposits in Hobble Canyon, Utah, and Lake Humboldt, southwest of Lovelock, Nevada.\textsuperscript{5}

Only recently we have received samples of material from Rigby, Idaho. This consisted of white crystalline salts, and gray and red rocks of volcanic origin, also a composite sample of the material. These gave on analysis the following results:

<table>
<thead>
<tr>
<th></th>
<th>White Crystals</th>
<th>Red Rock</th>
<th>Gray Rock</th>
<th>Composite Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNO\textsubscript{3}</td>
<td>87.40</td>
<td>2.71</td>
<td>1.22</td>
<td>11.00</td>
</tr>
<tr>
<td>NaNO\textsubscript{3}</td>
<td>3.66</td>
<td>0.60</td>
<td>0.88</td>
<td>40.65</td>
</tr>
</tbody>
</table>

We have been unable as yet to obtain accurate information as to the extent or possibilities of this deposit, but since the rock itself contains about three per cent of mixed nitrates of sodium and potassium, it looks very promising.

In the western part of Millard County, Utah, White Valley, an old alkaline lake bed is located, and efforts are being made to develop this region as a source of potassium. An analysis of a sample taken from the top 18 inches of this bed gave the following results:

Soluble salts 11.84%: calcium (Ca) 0.46%; magnesium (Mg) 0.20%; carbon dioxide (CO\textsubscript{2}) 2.10%; sulphates (SO\textsubscript{4}) 1.34%; chlorine (Cl) 5.54%; potassium (K) 0.99%; and sodium (Na) (by difference) 1.21%.

The result of other analyses and description of the area are as follows:\textsuperscript{1}

"The old lake bed, the receptable for untold ages of the washing and leaching from the potash ledges of the mountains near by, is in dimensions about three by fourteen miles, and the assays show about four per cent of potash in the clay and water menstruum at a depth of twenty feet. The underground permanent

\textsuperscript{4} Commercial Fertilizer, June 1916.
\textsuperscript{5} The Potash Supply, published by German Kali Syndicate.
\textsuperscript{1} Letter from W. H. Jones.
water is struck at about seventeen feet and above this point the potash content is slightly less; indeed, the clear underground menstruum, settled for twenty-four hours and then filtered, carried .70 plus per cent of potash in chemical solution itself.

“You will perceive that, estimated at four or four and a half per cent with perhaps hundreds of feet in depth, there are here many thousands, nay millions, of tons of clay or mud deposit worth $10 per ton in every quarter section, and hundreds of millions of potash in the aggregate deposit, a matter of vast concern as a resource to our state or commonwealth.

“The material consists essentially of clay, silica, calcium carbonate and magnesium carbonate, together with six per cent of soluble salts (in another report seven per cent and in another four and a fourth per cent soluble salts). These latter consist of sodium sulphate, sodium chloride, and potassium sulphate, together with a very small proportion of calcium sulphate, magnesium sulphate and sodium carbonate.”

Salt beds are being exploited in very many localities. It is likely that at some future time the salt deposits of the arid West will compete with Stassfurt in the production of salts of potassium.

Beet sugar molasses contains from ten to fifteen per cent ash, and of this about three-fourths is salts of potassium. A good sample of beet molasses ash gave an analysis 45.3% potassium carbonate, 22.4% potassium chloride, 8% potassium sulphate, 13.86% sodium chloride, and 15.82% of silica, lime, alumina, water, phosphoric acid, etc.\(^1\) The beet sugar industry of Germany produces annually 15,000 tons of potash salts. Dust from cement plants is being collected and concentrated for its potassium salts. In all, about $342,000 worth of potassium salts were produced in the United States in 1915.\(^2\)

**Potassium from Native Vegetation.**

Numerous inquires have been received by the Chemistry Department of the Utah Experiment Station as to the value of sage brush ash as a source of potassium. Since so far as we knew

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little positive information on this point was available we collected samples as follows:

Sage brush (Artemesia tridentata)..............College Hill
White Sage (Artemesia tridifida)..............College Hill
Rabbit brush (Chrysothomus greenier).........College Hill
Brigham tea (Ephedra trifurca)..........Southern part of State
Sage brush ash.........................................Parowan, Utah
Greasewood (Sarcobatus vermiculatus)........Preston, Idaho

These samples were ashed and the potassium was then determined in the ash. The dry matter was also determined in order that all might be converted to a uniform basis. These plants are very woody in nature and as a consequence have rather high dry matter content. The dry matter content is as follows:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Dry Matter Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush</td>
<td>75.66%</td>
</tr>
<tr>
<td>White sage</td>
<td>61.08%</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>83.31%</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>89.56%</td>
</tr>
<tr>
<td>Greasewood</td>
<td>79.03%</td>
</tr>
</tbody>
</table>

As will be noted the dry matter varies from 60 per cent in White sage to 89 per cent in Brigham tea.

The following results were obtained by ashing the plants:

Results Expresed as Per Cent.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Ash Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush</td>
<td>10.47%</td>
</tr>
<tr>
<td>White sage</td>
<td>11.89%</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>5.78%</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>5.84%</td>
</tr>
<tr>
<td>Greasewood</td>
<td>7.63%</td>
</tr>
</tbody>
</table>

Both sage brush and white sage are very high in ash, as will be observed from the table, each containing more than ten per cent. Thus, one ton of dry sage brush would yield over two hundred and forty pounds. The rabbit brush and Brigham tea contain about half as much ash as the sage brush and white sage, and the greasewood, which grows so luxuriantly on many alkali lands, contains nearly 8 per cent of ash.
The potassium (K) in the ash was as follows:

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Potassium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush (College Hill)</td>
<td>4.10%</td>
</tr>
<tr>
<td>Sage brush ash (Parowan, Utah)</td>
<td>5.42%</td>
</tr>
<tr>
<td>White sage</td>
<td>13.77%</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>13.04%</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>5.94%</td>
</tr>
<tr>
<td>Greasewood</td>
<td>12.61%</td>
</tr>
</tbody>
</table>

It will be noticed that both the white sage and rabbit brush are considerably higher in potassium than are the other samples, being 13.77 per cent and 13.04 per cent respectively. Then follows greasewood with 12.61 per cent and then the Brigham tea, then the sage brush ash from Parowan and lastly that from the College Hill. It may be observed that the sample from Parowan is almost 2 per cent higher than that prepared by us. It is well known that the same variety of plants growing in different localities on different types of soil take from the soil different proportions of the mineral elements. From the dry matter in the plant, the ash, and potassium in the ash, the potassium in the dry plant was calculated with the following results:

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Potassium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush</td>
<td>0.43%</td>
</tr>
<tr>
<td>White sage</td>
<td>1.64%</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>0.75%</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>0.35%</td>
</tr>
<tr>
<td>Greasewood</td>
<td>0.96%</td>
</tr>
</tbody>
</table>

It may be observed that the potassium content in the dry plants follows the same order as the potassium in the ash except that sage brush contains a higher percentage of potassium than does the Brigham tea. This is due to the lower dry matter content in the former as compared with the latter.

The potassium content in pounds of potassium per ton of ash is as follows:

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush (College Hill)</td>
<td>82.0 pounds</td>
</tr>
<tr>
<td>Sage brush ash (Parowan, Utah)</td>
<td>108.4 pounds</td>
</tr>
<tr>
<td>White sage</td>
<td>275.4 pounds</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>260.8 pounds</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>118.8 pounds</td>
</tr>
<tr>
<td>Greasewood</td>
<td>252.2 pounds</td>
</tr>
</tbody>
</table>
SOME SOURCES OF POTASSIUM

This varies from nearly 100 pounds per ton of ash in sage brush from College Hill to almost 300 pounds in one ton of white sage ash. In the plant itself the potassium content varies from seven pounds per ton of dry plant in the Brigham tea to 32.8 pounds per ton of dry plant in the white sage. The sage brush gives 8.6 pounds and the rabbit brush 15.0 pounds per ton.

The Value of Potash.

Prior to 1914 the price of potassium was about six cents a pound, but due to the elimination of the German supply this cost has risen until now it is about thirty-eight cents a pound. That is, the price of the chloride of potassium seems to be stationary at about $400 for a ton of 2,000 pounds. In potassium chloride it is only the potassium which is valuable for fertilizing purposes. Potassium chloride contains 52.44% of the element potassium itself, and consequently one ton of potassium chloride or muriate of potash, as it is commonly called in fertilizer papers, contains 1,048 pounds of potassium and costs about $400, or about thirty-eight cents a pound for the element potassium. Using these values for computation we find that one ton of the ash of each of these plants would have value as follows at six cents per pound:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush (College Hill)</td>
<td>$4.92</td>
</tr>
<tr>
<td>Sage brush ash (Parowan, Utah)</td>
<td>6.50</td>
</tr>
<tr>
<td>White sage</td>
<td>16.52</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>15.65</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>7.12</td>
</tr>
<tr>
<td>Greasewood</td>
<td>15.13</td>
</tr>
</tbody>
</table>

By using the present value of thirty-eight cents per pound the potassium in one ton of each ash would be worth $31.16, $41.19, $104.65, $99.10, $45.15, and $95.74 respectively.

At six cents per pound for potassium each ton of dry plant is worth as follows:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sage brush (College Hill)</td>
<td>$.53</td>
</tr>
<tr>
<td>White sage</td>
<td>1.97</td>
</tr>
<tr>
<td>Rabbit brush</td>
<td>.90</td>
</tr>
<tr>
<td>Brigham tea</td>
<td>.42</td>
</tr>
<tr>
<td>Greasewood</td>
<td>1.15</td>
</tr>
</tbody>
</table>
and at the advanced price of thirty-eight cents per pound: $3.26, $12.44, $5.70, $2.66, and $7.30 respectively.

The potassium salt most likely to be present in the ash is the carbonate, and in lesser amounts the chloride and sulphate. These are all quite soluble in water, especially the carbonate; and hence it should be rather an easy matter to leach the sage brush ash and concentrate it by means of solar heat.

At 0° C. 89.4 pounds of potassium carbonate is soluble in 100 pounds of water. Potassium chloride is somewhat less soluble, 28.5 pounds going into solution in 100 pounds of water at the same temperature, while potassium sulphate is still less soluble than the chloride, for at 0° C. only 8.5 pounds is soluble in 100 pounds of water. Water standing in the sun in barrels during the summer would have a temperature of from 30° to 40° C., and at this temperature the solubility of the salts would be increased. Since one gallon of water weighs about eight pounds, the potassium in one ton of sage brush ash would be soluble in from fifteen to twenty gallons of water. In many localities of the arid west the sage brush grows luxuriantly on lands not suited to agricultural use. From such lands the sage brush might be burned and the potassium recovered, and furthermore, from much of the new agricultural land the sage brush must be removed either by burning on the land or hauling away. It seems that at slightly increased expense this ash might be collected and leached with water in a series of barrels by passing the water from one to another and the water then evaporated from wide open vats by means of solar heat or from the waste heat of the burning sage brush. The crystallized material could then be shoveled up. In this way both the volume and weight would be very materially decreased, and the percentage of potassium in the residue left after evaporation would be decidedly higher than in the ash itself. In this way the transportation charges might be greatly reduced.

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