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The Active Potash of the Soil and its Relation to Pot Experiments

BY
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THE ACTIVE POTASH OF THE SOIL AND ITS RELATION TO POT EXPERIMENTS.

BY

G. S. FRAPS, CHEMIST.

This is a technical bulletin intended for scientific readers only. The application of the information secured in this work to Texas oils will be made in later publications.

By "active potash" we mean the potash soluble in fifth-normal itric acid. It is the object of our work to ascertain the origin of he potash dissolved by this solvent, and its significance to soil chemstry.

HISTORICAL.

Active potash and phosphoric acid were usually studied together.

Gerlach (1) states that from several hundred experiments on dilute olvents for two years with 16 soils, a 1 per cent citric acid best erves to indicate the needs for phosphoric acid. There are, however, xceptions not yet explained.

Dyer (2) found the root acidity of 100 plants to vary from 0.34 with olanaceae to 3.4 with Rosaceae and averaged 0.91 per cent. He aplied 1 per cent citric acid to soils of known character of the Rothamted Experiment Station and found the results with potash and phoshoric acid in accordance with the history and properties of the amples. He concludes that a soil containing less than .01 per cent otash or phosphoric acid soluble in this solvent is usually in need f a corresponding fertilizer.

The American Association of Official Agricultural Chemists (3), rough various Referees, undertook studies of citric acid and other lvents.

The Experiment Station at Halle (5), Germany, uses weak citric id.

Liebscher (6) obtained results in accordance with those of Dyer.

The Hatch Experiment Station (7) obtained results which did not rrespond with the yield.

Sap acidity of wheat (8) was found to be equal to 0.48 per cent tric acid, of clover 1.02 per cent. Hall and Plymen (9) tested per cent citric acid, equivalent hydrochloric acid, acetic and water turated with carbon dioxide, on 19 soils. The 1 per cent citric id gives results most nearly in agreement with the recorded history the soil, though there is evidence that the same interpretation canot be placed on results obtained from all types of soils.

Cousins and Hammond (10) found Dyer's method unsatisfactory the highly calcareous soils of Jamaica, unless first neutralized; en they agreed with the known productiveness.

Kudashey (11) recommends ½ per cent oxalic acid and reports sults on 62 samples of soils.

The Dyer method agreed with field tests on clay soils but not with other types of soils (12).

Moore (4) compares the quantity of potash and phosphoric acid extracted from the soil by dilute acids, with the quantity removed by crops from the soil, regardless of the deficiencies of the soils for any particular plant food. On the basis of this work he proposed the use of one-two hundredth normal hydrochloric acid.

Buler (13) states that water containing carbon dioxide gives better results than dilute acids. A soil containing less than 0.015 per cent potash soluble in carbonated water is deficient.

Ingle (14) found that extraction with 1 per cent citric acid makes the soil less productive at first, but the active plant food is gradually restored.

REFERENCES.

(1) Gerlach, Experiment Station Record 3, 208.
(2) Dyer, Experiment Station Record 5, 1013, from Journal Chem. Soc., 1894, 115.
(3) Report of Referee on Soils, Bulletins 47, 49, 51, 56, 67, 73, Division of Chemistry, U. S. Dept. of Agriculture.
(4) Moore, Jour. Am. Chem. Soc., 1902, page 109.
(5) Experiment State Record 5, 471.
(6) Experiment Station Record 7, 664.
(7) Experiment Station Record 11, 508.
(8) Experiment Station Record 11, 1018.
(9) Experiment Station Record 13, 914.
(10) Experiment Station Record 15, 335.
(11) Experiment Station Record 17, 527.
(12) Wannes, Experiment Station Record 18, 208.
(13) Ann. Agric. de la Suisse, 1909, 161.
(14) Chemisches Centralblatt, 1905, 1, 285.

FACTORS OF AVAILABILITY OF PLANT FOOD.

The amount of any given plant food which is withdrawn from the soil by the plant does not depend upon one condition only, but is dependent upon and conditioned by a number of factors. (Fraps, Amer. Chem. Jour., 32, 1904.) These factors may be grouped as follows:

(1) The quantity of the element present at the beginning of the growing season in forms of combination which can be partly or completely absorbed by the plant. This may be called *chemically available* plant food.

(2) The condition of the soil particles. Compounds chemically available may be enclosed in the soil particles so as not to be exposed to the action of plant roots. Such compounds are *physically unavailable*. If the incrusting substance is removed, such bodies become chemically available.

(3) The amount of the plant food transformed during the growing season into forms of combination which can be absorbed by plants. The factor is certainly of importance with respect to nitrogen; its importance in the case of phosphoric acid and potash is apparently

not so great; but the matter requires study. This factor may be called *weathering availability*.

(4) The nature of the plant. Plants differ in both their capacity for absorbing food and their need of it. Whatever the cause of such differences, there is no doubt but that they exist. We call this factor *physiological availability*.

The character of the soil, its chemical composition, the conditions which prevail during the growth of the plant, and perhaps other factors influence the amount of plant food taken up.

METHODS FOR ESTIMATION OF POTASH.

The potash of the soil is estimated by three groups of methods:

(1) By complete decomposition of the soil, and the estimation of all the potash contained therein. This method gives the total quantity of potash in the soil, but what the particular significance of the potash is with respect to soil fertility has not yet been made clear. A large portion of such potash is in highly insoluble form.

(2) By partial decomposition of the soil with strong hydrochloric acid. This method indicates the wearing qualities of the soil.

(3) By extraction with dilute acids. This method is proposed to estimate potash in such forms as are easily taken up by plants, and that estimated by N/5 nitric acid is termed "active potash" in this bulletin.

METHOD OF ANALYSIS.

The following are the methods used by us for active phosphoric acid, active potash, and acid consumed:

Weigh 200 gm. soil into a 2¼ liter glass stoppered bottle. Add exactly 2000 cc. N/5 nitric acid, measured with a flask. Place in a water bath previously heated to 40° C. Digest five hours, shaking every half hour. Filter on a large double fluted filter. When cold, take 1600 cc. for the estimation of phosphoric acid and potash, and save the remainder of the filtrate for "acid consumed."

Evaporate the 1600 cc. at first in a large dish on the steam bath, then in small dish on the steam bath, add about 10 cc. hydrochloric acid when nearly dry, evaporate to complete dryness on water bath, and heat in air bath to render silica insoluble. Take up residue in water, add a few drops of hydrochloric acid, and filter into a 100 cc. flask. Make up to volume. When the soil contains considerable lime, the liquid cannot be evaporated completely in a water bath, but should be covered and placed in a drying oven, and the temperature raised slowly until the mass is sufficiently dried.

Phosphoric Acid.—Take 50 cc. for phosphoric acid (do not wash out pipette with liquid, as exactly 50 cc. must be left). Add 10 cc. nitric acid, make alkaline with ammonia, then very slightly acid. Add 10 to 20 cc. molybdate solution, and digest at a temperature below 50° C., for three hours. Filter and titrate as usual for phosphoric acid. Use the 50 cc. remaining for the estimation of potash.

The volumetric method is, in our opinion, more accurate for soils than the gravimetric method.

Potash.—Wash the 50 cc. reserved above into a porcelain evaporating dish and evaporate once with a large excess of hydrochloric acid. Dissolve in water and acidify with hydrochloric acid sufficient to take up the basic salts formed by evaporation, and then evaporate with platinum solution after acidifying. Complete as in Moore's method. Protect from ammonia fumes at all times. It is important that the nitric acid should be completely removed.

Acid Consumed.—Heat 10 cc. of the filtrate to boiling, boil three minutes, titrate with N/10 NaOH and phenolphthalein. Make a blank on the original nitric acid solution, and calculate the percentage of the acid which was consumed by the soil. The quantity of "acid consumed" is a measure of the lime and magnesia which neutralizes the solvent.

Correction for Neutralization.—The above method does not provide that the strength of the solvent should be increased to allow for the acid neutralized by the lime (see Bulletin 126, this Station). We do not believe such a correction should be made, excepting possibly with calcareous soils which neutralize 80 per cent or more of the acid. Even with such soils, however, further experiments must decide which procedure will give the more satisfactory results. Analyses of soils of such character are exceedingly difficult to interpret, because the dissolved carbonate of lime may contain plant food which is not exposed to the roots of the plant.

FACTORS OF INFLUENCE ON THE COMPOSITION OF THE SOIL EXTRACT.

The amount of potash extracted from the soil by a given solvent is the difference between that dissolved from the potash minerals and that absorbed by the fixing particles of the soil. That is to say, the soil extract does not necessarily represent the solubility of the potash minerals exposed to the action of the solvent, but is the resultant of the solvent and fixative forces. Furthermore, the quantity of potash minerals exposed to the action of the solvent depends upon their condition in the soil and the solubility of the protecting material in the solvent used. If the mineral is enclosed within quartz, it is quite effectually protected from any solvent. If it is contained within zeolites, it may be affected by some solvents and not by others. If it is contained in carbonate of lime, the latter will be dissolved by any acid solvent, with consequent exposure of the included potash mineral to the action of the solvent.

The quantity of potash contained in the soil extract may depend upon three factors:

(1) The quantity of potash minerals exposed to the solvent, and its solubility under the conditions of the extraction.

(2) The solubility of the soil materials which protect or enclose potash minerals.

(3) The power of the soil to fix potash under the conditions of the extraction.

The strength of the solvent, its nature, the period of digestion, the temperature, and the proportion of soil to solvent, all affect the quantity of potash contained in the soil extract, but they have their effect through action on the three factors mentioned above.

POTASH MINERALS OF THE SOIL.

A large number of minerals are known to contain potash, but we have little information concerning their occurrence in the soil, or their relative values as sources of potash to plants. Potash minerals may, in general, be said to belong to three groups:

(1) Unchanged particles of minerals from igneous rocks, such as felspar, or microcline. These are well known to be present in soils.

(2) Secondary minerals, formed by the weathering agencies upon the primary minerals, and, in general, more easily acted upon by solvents.

(3) Absorbed potash held by minerals, being the potash liberated by weathering, or added in manures or fertilizers, and held by minerals in a loose form of combination.

POTASH DISSOLVED BY STRONG ACIDS.

Minerals containing potash were brought in contact with strong hydrochloric acid, as used for soils by the (*American*) Association of Official Agricultural Chemists. The quantity of mineral containing 0.1 gm. potash was heated with 100 cc. hydrochloric acid, sp. gr. 1.115. The results are as follows (see Table 1):

The potash of nephelite, leucite, glauconite, and biotite was completely removed. Thirty-seven per cent of the potash of muscovite (one sample) was dissolved. Two samples of microcline and four samples of orthoclase gave up 0 to 4 per cent of their potash. We conclude that the potash dissolved from the soil by strong acid does not come from orthoclase or microcline, except to a slight extent.

It may come from biotite, or hydrated silicates, or partly from muscovite. The potash undissolved by *strong* hydrochloric acid is thus largely in the form of feldspar.

POTASH SOLUBLE IN WEAK ACIDS.

The potash soluble in weak acids was studied in order to ascertain the source of the potash removed when the active potash is estimated in soils. The solvent chiefly studied was fifth-normal nitric acid, though other solvents are being considered. The ratio of soil to solvent was 0.5 gm. potash to 1000 cc. acid. The minerals were ground to pass a 100 mesh sieve and the methods were the same as for soils. This would correspond to a soil containing 0.5 per cent potash, since in soil analysis 100 grams are treated with 1000 cc. solvent. (See Table 1.)

The minerals may be divided into three groups according to their behavior to N/5 nitric acid.

(1) Practically no potash removed.—Microcline and orthoclase.

(2) Less than 10 per cent potash removed—Glauconite and biotite.

(3) From 15 to 60 per cent potash removed.—Muscovite, nephelite, leucite, apophyllite, phillipsite.

When the mineral is in a coarser state of division, a smaller percentage is dissolved.

Solubility in 0.5 *and* 2 *N. Acid.*—Tests of the solubility of minerals in 0.5 and 2 N nitric acid also were made as previously described. Increasing the strength of the acid had practically no effect upon the potash dissolved from microline, orthoclase, biotite, glauconite and muscovite. Only with nephelite, leucite, and apophyllite, were there marked changes in the quantity of potash dissolved as the acid was stronger.

There was thus no one mineral from which the N/5 nitric acid dissolved all the potash. The potash dissolved by this acid, therefore, represents a *part* of the potash in the form of the more easily decomposed minerals, and not *all* of such potash.

TABLE 1—POTASH EXTRACTED BY SOLVENTS FROM MINERALS.

Laboratory No		Percentage of Potash Dissolved by—				Total Potash in the Mineral—Per Cent.
		Strong Hydrochloric Acid.	N/5 Nitric Acid.	N/2 Nitric Acid.	2 N Nitric Acid.	
1177	Microcline	4.00	0.90	1.00	1.30	10.14
1180	Microcline	4.00	1.30	1.30	1.50	12.50
224	Microcline	3.00	1.60	1.20	0.80	12.58
720	Microcline	0.50	0.80	2.20	----------	10.70
725	Microcline	3.00	0.80	2.00	----------	12.36
1178	Orthoclase	0.00	1.10	1.20	1.40	11.81
718	Orthoclase	4.00	0.70	1.90	----------	12.58
730	Orthoclase	----------	1.30	0.40	----------	12.40
1176	Biotite	100.00	26.40	29.00	----------	8.40
2563	Biotite	----------	26.70	----------	----------	9.62
261	Biotite	100.00	----------	----------	----------	----------
1175	Glauconite	100.00	5.40	5.80	12.00	4.28
1174	Glauconite	----------	5.00	5.40	6.30	6.38
1179	Muscovite	37.00	17.10	16.40	16.60	10.12
734	Muscovite	52.00	18.00	18.00	21.30	9.40
2397	Muscovite	----------	26.00	----------	----------	9.31
258	Nephelite	100.00	49.30	65.60	96.70	2.86
711	Leucite	100.00	56.60	86.20	100.00	17.31
717	Apophyllite	----------	67.50	89.00	----------	2.38
1388	Apophyllite	----------	58.10	----------	----------	2.14
1405	Phillipsite	----------	58.50	----------	----------	1.35
1393	Pinite	----------	5.40	----------	----------	5.18

SOLUBILITY OF POTASH ABSORBED BY MINERALS.

The finely-ground minerals selected for this work were treated with a strong solution of sulphate of potash, and after remaining in contact twenty-four hours they were washed thoroughly and dried. The loosely-held potash was thus washed out. Potash was estimated in the original mineral and in the treated mineral, and the difference was assumed to represent absorbed potash.

A quantity of the treated mineral containing 0.25 gm. of potash was digested for five hours at 40° with 500 cc. of N/5 nitric acid, filtered, and potash determined in an aliquot of the filtrate. An equal weight of the original mineral was treated with acid in the same way and at the same time, and potash estimated. The difference in the two was assumed to represent absorbed potash dissolved by the solvent.

The results of this work are represented in Table 2. They are expressed in percentages of the potash present. From 3 to 100 per per cent of the original mineral potash were dissolved by the solvent. These figures, however, are not at all accurate, on account of the small amount of potash used.

From 36 to 100 per cent of the absorbed potash was extracted by the solvent N/5 nitric acid. The average recovery is 79 per cent. It is evident that the bulk of the absorbed potash dissolves in this reagent.

Solubility in 2% Ammonia.—As ammonia has been proposed as a solvent for soil potash, we tested its effect upon the potash absorbed. The mineral described above containing 0.25 gm. potash absorbed was digested twenty-four hours at room temperature with 1000 cc. of 2% ammonia. Two hundred cubic centimeters were evaporated to dryness, transferred to a platinum dish, ignited with 1 cc. sulphuric acid, taken up with acid and water and evaporated with platinum as usual.

TABLE 2—POTASH FIXED BY MINERALS AND DISSOLVED BY N/5 NITRIC ACID AND BY AMMONIA.

Laboratory No.		Per Cent of Potash In—		Percentage of Potash Dissolved by N/5 Nitric Acid From—		Percentage of Potash Dissolved by 2% Ammonia From—	
		Mineral.	Mineral After Treated with Potash Salts.	Mineral Potash.	Fixed Potash.	Mineral Potash.	Fixed Potash.
1387	Stilbite	0.28	3.95	27.00	80.00	18.00	11.00
1389	Stilbite	0.64	2.85	13.00	84.00	11.00	9.00
2392	Stilbite	0.17	4.09	18.00	63.00		
2552	Stilbite	0.28	4.40	34.00	68.00		
1394	Thomasonite	3.62	4.61	3.00	100.00	4.00	16.00
1401	Thomasonite	0.29	1.00				
1395	Natrolite	0.51	1.20				
1396	Natrolite	1.24	1.59	10.00	100.00	4.00	45.00
2996	Natrolite	0.34	1.37	8.00	93.00		
1400	Analcite	0.47	1.54	6.00	54.00	6.00	13.00
1402	Chabazite	0.90	4.82	48.00	83.00	16.00	14.00
2551	Chabazite	1.00	5.96	100.00	89.00		
2555	Heulandite	0.35	1.70	13.00	36.00		
3556	Pectolite	0.54	9.89	3.00	100.00		
	Average				79.00		18.00

The results of this experiment are also in Table 2. On an average, only 18 per cent of the absorbed potash was dissolved. We do not consider ammonia to be a good solvent for soil potash.

FIXATION OF DISSOLVED POTASH.

In our study of the phosphoric acid of the soil (Bulletin 126, this Station), we found that some soils have a very high power for withdrawing phosphoric acid from solution, so that it is not possible to tell with them whether much phosphoric acid is present in active forms or not. A similar study has been made of the potash of the soil.

Method of Work.—The method used is as follows: Weigh out two portions of 100 grams each. Add to one portion 1000 cc. of N/5 nitric acid. Add to the other 1000 cc. N/5 nitric acid containing about 20 mg. potash. Digest five hours at 40° as for active potash in soils, and finish as for active potash in soils using 800 cc. of the solution for the estimation.

Results.—Table 3 shows the results of a single experiment of this kind. Table 4 shows tests upon ten soils. Soils were selected for this work which had a comparatively high absorptive power for potash in preliminary tests in aqueous solutions. The analyses were made in duplicate.

We find that, although the soil has the power to withdraw potash from acid solution, yet this power is not great, and the absorptive power of the soil for potash is not by any means as great a factor in the estimation of active potash, as the absorption of phosphoric acid may be in the estimation of active phosphoric acid. In Table 11 of Bulletin 126, we find seven of the thirty-nine soils to fix over 65 per cent of the added phosphoric acid. The maximum fixation of potash we have is 42 per cent.

TABLE 3—POTASH ABSORBED BY A SOIL FROM ACID SOLUTION.

Laboratory No.		
1138	Parts per million potash in original soil	168.7
	Added potash	232.4
	Total which should be extracted	401.1
	Actually extracted	347.5
	Loss (absorbed)	53.6
	Percentage absorbed	23.0

TABLE 4—PERCENTAGE OF ADDED POTASH ABSORBED BY SOILS.

Laboratory No.		Percentage Absorbed.	Absorptive Power of Soil.
	240 parts per million of potash added:		
929		42	
1128		23	79
1138		26	68
1204		30	72
1205		25	69
1935		28	80
	Average	29	73
	198 parts per million of potash added:		
1127		13	56.5
1140		9	61.8
1131		13	67.8
1100		7	60.3

Soils with an average fixing power of 73.6 per cent (see next section for method) for potash from water, fix only on an average 29 per cent from N/5 nitric acid. Although this fixation will have an effect upon the quantity of potash secured from the soil, and should not be entirely disregarded, yet the fact that the potash dissolved does not represent all of any one class of potash compounds, but only a percentage thereof, renders the matter of this fixation of much less importance than with phosphoric acid.

FIXATION OF POTASH FROM AQUEOUS SOLUTION.

It is of some importance to know the relative fixing power of soils in connection with the foregoing statements. Table 5 contains a summary of the fixing power of such Texas soils as we have studied at the date of this Bulletin.

The estimation of fixing power was made as follows:

Fixation of Potash by Soils.—Strong Potash Solution. Secure a sample of sulphate of potash which has been subjected to analysis. (Fertilizer.) Dissolve the quantity containing a little over 4 grams potash (K_2O) and make up to 4000 cc. Determine the strength of the solution, using 10 cc. and treating directly with platinum. Dilute so that 10 cc.=.010 gram K_2O.

Weak Potash Solution.—Place 200 cc. strong potash solution in a graduated flask and make up to 2000 cc.

Place 50 grams soil in a glass stoppered bottle and add 200 cc. weak potash solution. Let stand twenty-four hours, shaking every half hour during the working hours. Filter, acidify 100 cc. of the filtrate with hydrochloric acid and evaporate to dryness in a room free from ammonia. Ignite gently, if necessary, to remove organic matter. Heat in drying oven to dehydrate silica, take up with hot water and a little acid, filter, acidify filtrate, and evaporate with 2 cc. platinum chloride. Complete as in Moore's method. Subtract the quantity of potash found from that which should be present in 100 cc. (.0100 gm.) and express results as percentage of potash fixed.

Table 5 shows the fixing powers for potash of 107 Texas soils. Those with over 70 per cent fixation power are 21.5 per cent of the total. It might be necessary to consider the fixation of these soils in connection with the estimation of active potash.

EFFECT OF SUCCESSIVE DIGESTIONS.

A number of soils were subjected to successive extractions with N/5 nitric acid. The soils were digested with acid as usual in the estimation of active potash, allowed to drain after filtering, and washed back into the bottle with N/5 nitric acid. The filtrate was measured. Five or more successive extractions were made. The results are presented in Table 6.

TABLE 5—FIXING POWER OF TEXAS SOILS FOR POTASH.

Fixing Power from Water.	Number of Samples.	Per Cent of Total.
Less than 10%	12	11.20
From 10-20%	10	9.30
From 20-30%	10	9.30
From 30-40%	9	8.40
From 40-50%	16	15.00
From 50-60%	8	7.50
From 60-70%	19	17.80
From 70-80%	17	15.90
From 80-90%	5	4.70
From 90-100%	1	0.90
Total	107	(100.00)

The extracted potash decreases with each extraction to about 25 to 100 parts per million in the fifth extraction. That is to say, the easily soluble potash is removed by the first several extractions, and then the dissolved potash represents only a small fraction of the highly insoluble potash minerals. The first extraction does not remove all the easily soluble potash, and we have seen that it does not extract all the potash from the minerals we tested on the first extraction, but leaves a portion to be removed by subsequent extractions.

TABLE 6—POTASH REMOVED BY SUCCESSIVE EXTRACTIONS, IN PARTS PER MILLION.

Laboratory No.		830	818	1122	2303	2301	2420
	Extraction No. 1	lost	248	167	1066	94	137
	Extraction No. 2	1030	76	75	1060	57	72
	Extraction No. 3	299	47	45	35	30	40
	Extraction No. 4	119	50	59	102	45	66
	Extraction No. 5	86	46	92	136	66	25

Varying Amounts of Solvent.—In this experiment, mineral containing 0.5 gm. potash was tested with 500, 1000 and 2000 cc. solvent, respectively. The results are presented in Table 7. Increase in volume of the solvent caused a slight increase in the percentages of potash dissolved.

TABLE 7—POTASH REMOVED FROM MINERALS BY DIGESTION WITH DIFFERENT AMOUNTS OF N/5 NITRIC ACID.

Laboratory No.		In Grams—			In Percentages—		
		500 cc.	1000 cc.	2000 cc.	500 cc.	1000 cc.	2000 cc.
224	Microcline	.0017	.0029	.0040	0.4	0.7	1.0
1175	Glauconite	.0144	.0153	.0188	3.6	3.8	4.7
1177	Microcline	.0033	.0045	.006	0.8	1.1	1.5
1178	Orthoclase	.0032	.0050	.0065	0.8	1.2	1.6

Varying Amounts of Mineral.—A fixed amount of solvent was treated with increasing quantities of minerals. The larger quantity of mineral caused a somewhat larger amount of potash to go into solution except in one instance. Expressed in percentages, the percentage decreases with increase in quantity of mineral. (See Table 8.)

With a soil containing 1 per cent potash in orthoclase or microcline, about 1 per cent of this potash would be dissolved—about 100 parts per million. If the soil contained 0.5 per cent of such potash, about 60 parts per million would be dissolved. The fineness of the mineral in the soil would of course affect the potash dissolved.

TABLE 8—VARYING QUANTITIES OF MINERAL POTASH TO 1000 cc. SOLVENT.

	0.1 Gm. Potash.	0.2 Gm. Potash.	0.5 Gm. Potash.	1.0 Gm. Potash.
Microcline—Grams potash dissolved	.0035	.0043	.0060	.0097
Orthoclase—Grams potash dissolved	.0031	.0049	.0072	.0123
Microcline—Percentage potash dissolved	3.5	2.2	1.2	1.0
Orthoclase—Percentage potash dissolved	3.1	3.5	1.4	1.2

SIGNIFICANCE OF THE DISSOLVED POTASH.

We consider that our experiments show the potash dissolved from the soil by N/5 nitric acid up to approximately 100 parts per million, represents a small percentage—1 or 2 per cent—of a comparatively large amount of potash-bearing silicates, such as fieldspar.

The exact quantity of potash originating in this way will depend upon the character of the mineral potash, its degree of fineness, quantity and distribution in the soil. The quantity of such potash dissolved will of course remain nearly constant when the soil is extracted successively a number of times with the same weak solvent. Furthermore, it will supply some potash to plants, in quantity depending upon soil and weather conditions, as well as on the factors referred to above.

The quantity of potash extracted in excess of approximately 50 parts per million represents a comparatively large percentage of a small quantity of soluble potash. The quantity of this potash will, therefore, decrease when the soil is extracted several times with the same weak solvent. This potash is not all of the same value to plants, but can very easily vary in the readiness with which it is taken up. In other words, plants do not necessarily withdraw the same quantity of potash from soils which contain the same amounts of active potash.

Relation to Acid Consumed.—The acid neutralized by the lime and magnesia dissolved from the soil is expressed in percentage of the acid used, as "acid consumed." The quantity of lime and magnesia dissolved of course increase as the acid is used up. The more lime and magnesia dissolved, the greater the possibility of these substances containing potash compounds, which may be thus exposed to the solvent, but are, nevertheless, protected from the action of the roots of plants. This introduces another element of uncertainty for which it is very difficult to correct.

The lime and magnesia going into solution of course decreases the strength of the acid. It has been proposed to correct for this decrease by making a preliminary test and using sufficient acid in addition to compensate for that neutralized by the bases. We do not believe such correction should be made, excepting with soils which very nearly neutralize the solvent (80 per cent acid consumed or more). The lime and magnesia come from silicates as well as from carbonates, and an increase in the strength of the acid is accompanied by a greater solvent action upon such silicates. Also by the method of correction used, after the digestion, the acid would not have the N/5 strength it was corrected to have.

RELATION OF POT EXPERIMENTS TO THE ACTIVE POTASH.

For about seven years we have been making pot experiments with representative Texas soils from different parts of the State. These experiments were carried on under varied conditions. With some of them the conditions were very favorable, while with other groups the conditions were not so suitable. The results are, therefore, not comparable one with another. We can, however, compare the crop produced on the pots receiving potash with those without potash.

From the work presented on the previous pages, it appears that the potash dissolved by fifth-normal nitric acid from a natural soil, in excess of 50 to 100 parts per million, as a rule, comes from the easily soluble potash compounds. It does not follow that soils containing the same quantity of easily soluble potash compounds should react in the same manner towards potash fertilizers. The potash compounds may be different in value in different soils.

The potash compounds which are dissolved by a solvent may be on the outside of soil particles, and exposed to plant roots, or within the soil particles, as already pointed out.

Reducing it to its lowest terms, the analysis of a soil with N/5 nitric acid amounts to this:

Knowing the quantity of potash extracted by the solvent, we can estimate how much easily soluble potash is present in the soil. Then, knowing the amount of acid consumed, we must judge to what extent this potash is distributed within the mass of the dissolved material, and to what extent it is exposed to the roots of the plants. Having estimated the amount of exposed potash compounds, we have next to inquire how much is necessary to make a soil fertile. What conditions affect the rate and the quantity of potash which these compounds give up? Then we have to consider the probable value of the highly insoluble compounds of potash, which are present.

CONDITIONS WHICH AFFECT PRODUCTION IN POTS.

In pot experiments, the attempt is made to keep all conditions constant except the one to be tested, maintaining the other as favorable as possible. It is, however, impossible to maintain only one variable. The main variable may be predominant, but there are others to be considered. Suppose, for example, we are studying the effect of potash on the soil, as is the case with much of the work here presented. We apply a complete fertilizer containing phosphoric acid, and nitrogen and potash, and compare its effect with a sample to which phosphoric acid and nitrogen only are added. The variable is thus potash. But in addition the potash may affect the bacterial life in the soil, and this effect may conceivably be either favorable or unfavorable to the development of the plant. The effect upon the bacterial life may vary in different soils. The potash may also have some effect upon the reaction of the soil, according to the kind of material used, and this may vary from soil to soil. The potash may affect the physical structure of the soil, etc. It is quite possible that these secondary reactions may on some soils have greater effect than the primary one, namely, the presence or absence of the potash.

It is obvious, however, that some controlling condition must limit the size of the crop in pot experiments, either the season and climatic conditions, the soil, or soil conditions. Suppose the conditions are so favorable that the potash in the soil and in the fertilizer, together, becomes the controlling condition. It is obvious that the potash of the soil cannot alone force as large a production as potash in the soil and in the fertilizer together so that the addition of potash will increase the yield, and the soil will appear to be deficient in potash. The soil may be an excellent one, and able to yield good crops without fertilizers, but if in our pot experiments other conditions are so favorable that the total and largest amount of potash becomes the limiting condition, the soil must appear as deficient, no matter how good it is. The crop from the unfertilized soil will be large, but that from the fertilized one will be larger. This is, of course, an extreme case. Seasonal conditions and the seed will often limit the crop. Yet it is possible in pot experiments to demand of the soil in the pot more than very fertile soils can accomplish in the field. We shall come back to this subject later, and in studying the quantity of potash removed in pot experiments, we shall find, at times, enormous quantities.

The conditions under which pot experiments are made are undoubtedly, in some respects, more favorable to the soil than field conditions. Some of the conditions may also be less favorable. In our work, the soil is well pulverized, and thus in a good mechanical condition. It is usually air-dry, and it has been shown that air-dried soils are perhaps more productive than the same soil not dried. The soil is sub-ventilated, and this is a distinct advantage, especially for heavy clayey soils. The temperature in the pots is higher than the temperature of the soil in the field. The application of results of pot experiments to field conditions is being made a subject of study by us.

METHOD OF WORK.

These pot experiments were not all conducted in exactly the same manner, but the general procedure is as follows:

Washed gravel was added in sufficient amounts to an 8-inch Wagner pot to make the total weight 2 kilograms. Five kilograms of soil was then added. The soil had been previously pulverized in a wooden box with a wooden mallet until it would pass a 3 mm. sieve, gravel being removed.

The addition of fertilizer consists of 2½ grams of acid phosphate, 1 gram nitrate of soda, and 1 gram sulphate of potash. In later experiments 1 gram of ammonium nitrate was used in place of nitrate of soda. If the size of the crop appeared to render it necessary, more nitrate of soda or sulphate of potash was added to the pot. They were added in solution, 10 cc. equals 1 gram, but, if added after planting, the solution was diluted with about 200 cc. of water.

The seed were weighed out so that each pot received the same amount of seed within 0.1 of a gram. Water was added to one-half the saturation capacity of the soil. If this quantity was found to be too great, it was afterwards reduced, but this was the case in only a few instances. The pots were weighed, placed on scales three times a week, and water added to restore the loss in weight. If the plants needed water between these weighings, such quantity was added as appeared necessary. The object of the weighing was to maintain as closely as possible a constant amount of water in the soil.

A few of these experiments were conducted in a greenhouse belonging to the Horticultural Department, and a number were made on trucks covered with wire mosquito netting. The trucks were pulled into the house when a storm threatened. Later experiments were made in houses covered with canvas. These houses appear to be very well suited to pot experiments under Texas climatic conditions. They are very much better for this purpose than glass houses for the reason that the circulation of the air is considerably better and the house does not become so heated. Many of the latter experiments were carried on in houses with glass roof and canvas sides. This appears to be the best form of houses for our climatic conditions for spring, summer and fall work.

In the following discussion we will consider all the crops which are shown in the table. There are some crops which should properly be excluded. We must also remember, in this connection, that on some soils, five or more crops were grown and on others only one. But we are dealing here with individual crops, and not with the soil.

GENERAL RESULTS.

Table 9 contains the results of 403 pot experiments on 172 soils arranged in groups according to the active potash contained in the soil. The table shows the "deficiency" based on the relation between crop in the completely fertilized crop, and the one without potash, the active potash in the soil, the weight of the crops with and without potash, the kind of growth, the year of the experiment, the percentage of potash in the crop, and the potash removed from the soil by the crop in parts per million.

Deficiency Based on Weight of Crop.—The results of the experiments, as regards deficiency of the soil based on weight of the crop, is presented in Table 10.

A crop is regarded as very deficient (DD) if it is only 50 per cent or less of the completely fertilized crop. If it is less than 90 per cent it is considered deficient (D). If more than 90 per cent it is considered as not deficient (S). Where the crop without potash is 110 per cent or more of the one with potash, it is marked (T).

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS.

GROUP 1—0-50 PARTS PER MILLION ACTIVE POTASH.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams. PN	Weight of Crop Per Pot Grams. PNK	Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
172	Norfolk sand	D	40	Corn	6.5	9.7	April 18—June 8	1906	3.00	43.0
	Norfolk sand	D		Cowpeas	5.9	10.2	April 18—June 8	1906		
	Norfolk sand	D		Oats	3.8	6.0	April 18—June 8	1906		
820	Susquehana fine sandy loam	D	47	Corn	6.8	12.5	April 6—May 27	1907		
859	Norfolk fine sand	D	40	Corn	17.5	29.8	May 3—June 6	1907	0.62	21.8
1592	Lufkin sand, subsoil	S	47	Mustard	7.0	6.9	September 15—November 3	1909	1.86	26.0
	Lufkin sand, subsoil	D		Sorghum	12.7	20.0	June 24—August 10	1909	0.58	14.8
	Lufkin sand, subsoil	D		Mustard	2.6	3.0	October 26—December 22	1909		
	Lufkin sand, subsoil	D		Corn	16.7	25.5	April 1—June 6	1910	0.62	20.8
	Lufkin sand, subsoil	DD		Sorghum	1.2	23.2	June 18—August 16	1910	0.90	2.2
1594	Houston black clay	D	45	Mustard	9.3	11.3	September 15—November 3	1908	2.86	53.4
	Houston black clay	D		Sorghum	16.4	22.7	June 24—August 10	1909	0.92	30.2
	Houston black clay	D		Mustard	3.5	6.5	October 22—December 22	1909	1.64	11.4
	Houston black clay	T		Corn	21.0	18.0	April 1—June 6	1910	1.27	53.2
	Houston black clay	D		Sorghum	32.2	40.9	June 18—August 16	1910	0.71	45.8

GROUP 2—50-100 PARTS PER MILLION ACTIVE POTASH.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	PN	PNK	Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
97	Heavy black rice soil	S	74	Cotton	7.4	6.9	July 20—September 8	1905		
141	Rice soil, cultivated three years	T	60	Cotton	5.5	3.6	July 20—September 8	1905		
211	Probably Norfolk sand	S	70	Corn	5.2	4.9	April 18—June 8	1906		
	Probably Norfolk sand	D		Oats	5.6	7.5		1906		
314	Norfolk fine sand	S	97	Corn	9.8	10.7	April 18—June 8	1906		
	Norfolk fine sand	D		Cowpeas	7.4	9.4		1906		
	Norfolk fine sand	S		Oats	4.9	4.5		1906		
316	Norfolk fine sandy loam	D	83	Corn	9.8	12.1	April 18—June 8	1906		
	Norfolk fine sandy loam	D		Cowpeas	6.1	7.7		1906		
	Norfolk fine sandy loam	DD		Oats	3.0	7.0		1906		
318	Lufkin fine sand	T	71	Corn	5.5	4.9	April 18—June 8	1906		
	Lufkin fine sand	T		Cowpeas	3.2	2.6		1906		
	Lufkin fine sand	S		Oats	7.0	6.9		1906		
819	Norfolk fine sandy loam	DD	82	Corn	3.0	18.2	April 6—May 11	1907	5.80	34.8
893	Lufkin clay	T	78	Corn	6.8	5.5	September 7—November 12	1907		
	Lufkin clay	DD		Grass	0.9	4.6	January 28—June 3	1908		
	Lufkin clay	D		Mustard	0.8	1.3	October 16—December 14	1908		
1129	Lufkin silt loam	S	70	Corn	35.0	36.5	April 27—June 22	1908	0.78	54.6
	Lufkin silt loam	DD		Sorghum	3.9	16.2	June 18—August 16	1910	0.71	5.6

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS—continued.

GROUP 2—50-100 PARTS PER MILLION ACTIVE POTASH—continued.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams.		Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of of Soil.
					P N	P N K				
932	Miller silt loam	DD	83	Corn	2.1	6.2	September 7—November 12	1907		
	Miller silt loam	D		Grass	3.6	6.7	January 28—June 3	1908		
3655	Orangeburg fine sand	D	91	June corn	25.0	29.5	July 9—August 25	1910	0.77	38.6
	Orangeburg fine sand	D		Oats	3.7	4.2		1910		
3656	Orangeburg fine sandy loam	S	61	June corn	19.7	20.4	July 9—August 22	1910	1.13	44.6
	Orangeburg fine sandy loam	S		Oats	6.2	6.7		1910		
3657	Orangeburg fine sandy loam	T	90	June corn	21.0	17.9	July 9—August 24	1910	0.93	39.0
	Orangeburg fine sandy loam	S		Oats	9.5	10.7		1910		
1200	Nueces fine sand	D	70	Corn	8.0	16.0	April 30—June 23	1908	1.48	26.8
	Nueces fine sand	D		Mustard	5.2	7.4		1908		
1578	San Antonio clay loam	T	67	Mustard	11.2	9.7	September 15—November 3	1908	2.33	52.2
	San Antonio clay loam	D		Sorghum	14.5	16.1		1909		
	San Antonio clay loam	D		Kafir	3.8	4.8	August 24—October 4	1909		
	San Antonio clay loam	T		Mustard	5.2	3.2	October 26—December 22	1909		
	San Antonio clay loam	D		Corn	21.0	24.0	April 1—June 6	1910	1.40	58.8
	San Antonio clay loam	DD		Sorghum	2.2	6.2	June 1—August 16	1910	1.43	6.2
1585	Willis sand	DD	90	Mustard	3.3	9.7	September 15—November 3	1908	3.02	20.0
1587	San Jacinto clay, subsoil	S	63	Mustard	9.9	9.3	September 15—November 3	1908	1.80	36.0
	San Jacinto clay, subsoil	D		Sorghum	21.0	24.3	June 24—August 10	1909	0.69	29.0
	San Jacinto clay, subsoil	D		Kafir	5.2	8.1	August 16—October 4	1909	1.01	10.6
	San Jacinto clay, subsoil	D		Mustard	4.6	5.3	October 20—December 22	1909	0.73	6.6
	San Jacinto clay, subsoil	D		Corn	19.5	25.4	April 1—June 6	1910	0.68	26.6
	San Jacinto clay, subsoil	DD		Sorghum	11.8	35.0	June 18—August 16	1910	0.70	16.6
1590	Lufkin sandy loam, deep subsoil	T	97	Mustard	4.9	4.2	September 10—November 3	1908	2.19	25.4
	Lufkin sandy loam, deep subsoil	D		Sorghum	13.3	17.6	June 24—August 10	1909	2.11	56.2
	Lufkin sandy loam, deep subsoil	D		Corn	23.0	29.3	April 1—June 6	1910	1.03	49.0
	Lufkin sandy loam, deep subsoil	D		Sorghum	6.9	4.9	June 18—August 16	1910	0.80	11.0
1591	Lufkin sand	S	62	Mustard	7.5	7.5	September 15—November 3	1908	2.06	31.0
	Lufkin sand	T		Mustard	6.0	3.9	October 26—December 22	1909	0.87	10.4
	Lufkin sand	D		Corn	18.0	27.2	April 1—June 6	1910	0.76	27.6
	Lufkin sand	DD		June corn	4.9	25.2	June 18—August 16	1910	0.72	7.0
1130	Lufkin silt loam	T	79	Corn	33.6	29.0	April 30—June 23	1908	1.40	94.0
	Lufkin silt loam	T		Mustard	2.5	0.1	October 22—December 18	1908	0.53	2.6
1586	San Jacinto clay	S	60	Mustard	10.0	10.2	September 15—November 3	1908	1.81	36.2
	San Jacinto clay	D		Sorghum	22.2	26.5	June 24—August 10	1909	0.35	15.6
2348	Norfolk fine sand	S	82	Mustard	2.0	2.3	November 9—December 22	1909	2.52	10.0
	Norfolk fine sand	T		Corn	37.0	35.0	April 1—June 3	1910	1.03	76.2
	Norfolk fine sand	D		June corn	4.0	5.1	July 19—August 16	1910	1.18	9.4

2351	Susquehana fine sandy loam, subsoil	S	92.2	Corn	16.2	15.0	April 1—June 6	1910	2.35	74.2
911	Norfolk fine sand	DD	68.7	Grass	0.3	2.5	January 28—June 3	1908		
910	Houston black clay	S	98.7	Corn	6.1	6.5	September 7—November 12	1907		
	Houston black clay	S		Grass	5.8	5.4	January 28—June 3	1908		
	Houston black clay	S		Mustard	8.1	8.2	October 16—December 14	1908	4.35	70.4
	Houston black clay	S		Sorghum	23.2	22.1	June 22—August 11	1909		
2350	Susquehana fine sandy loam	S	86	Mustard	3.0	2.9	January 9—February 10	1909	1.29	7.8
	Susquehana fine sandy loam	DD		Corn	23.5	48.0	April 1—June 3	1910	1.20	56.4
	Susquehana fine sandy loam	D		Sorghum	27.0	46.4	June 18—August 16	1910	0.54	29.2
2826	Sherman fine sandy loam	D	89	Corn	36.7	48.5	April 1—June 7	1910	1.95	143.2
	Sherman fine sandy loam	D		June corn	16.2	29.4	July 19—August 31	1910	0.83	26.8
348	Norfolk fine sand	D	95	Corn	10.1	12.5	July 19—September 3	1906	1.34	30.0
828	Norfolk fine sand	S	96	Corn	17.5	19.2	April 17—June 11	1907	1.28	44.8
860	Orangeburg fine sand	D	71	Corn	25.0	36.1	May 3—June 6	1907	0.94	47.0
	Orangeburg fine sand	DD		Corn	0.5	2.5	September 11—November 12	1907		
2353	Norfolk fine sand, subsoil	T	94	Mustard	3.0	1.6	November 12—December 22	1909	2.88	17.2
	Norfolk fine sand, subsoil	D		Corn	19.1	26.6	April 1—June 6	1910	1.14	43.6
	Norfolk fine sand, subsoil	D		June corn	17.2	29.4	July 9—August 21	1910	0.57	19.6
2948	Houston clay	S	86	Corn	10.6	10.0	April 1—June 6	1910	3.96	84.0
	Houston clay	D		Sorghum	43.0	47.4	June 28—August 24	1910	0.99	86.0
108	Yazoo sandy loam	S	75	Cotton	5.6	6.1	July 20—September 8	1905		

GROUP 3—100-150 PARTS PER MILLION ACTIVE POTASH.

1596	Austin clay, subsoil	T	120	Mustard	7.6	4.0	September 15—November 3	1908		
	Austin clay, subsoil	D		Sorghum	18.0	20.6	June 24—August 10	1909		
	Austin clay, subsoil	T		Kafir	6.2	5.6	August 16—October 4	1909		
137	Rice soil	S	128	Cotton	5.2	4.9	July 25—September 8	1905		
328	Blanco loam	DD	149	Corn	6.1	10.2	July 19—September 3	1906	6.55	88.1
	Blanco loam	T		Oats	12.0	9.0		1907		
338	Yazoo clay	T	140	Corn	15.1	12.0	July 19—September 3	1906	4.33	144.0
346	Norfolk fine sandy loam	D	110	Corn	2.0	2.8	July 19—September 3	1906	6.51	23.3
	Norfolk fine sandy loam	D		Oats	5.0	6.0		1907		
817	Lufkin fine sandy loam	T	145	Corn	30.0	26.2	April 6—July 6	1907	2.11	126.6
	Lufkin fine sandy loam	S		Corn	3.9	3.8	September 11—November 12	1907		
	Lufkin fine sandy loam	S		Grass	2.8	2.5		1908		
822	Lufkin fine sandy loam	S	150	Corn	21.2	20.6	April 6—May 11	1907	2.67	113.2
1125	Winfield fine sand	S	107	Corn	32.0	32.0	April 27—June 18	1908	1.62	103.6
	Winfield fine sand	D		Mustard	1.1	3.5	October 22—December 18	1908		
	Winfield fine sand	D		Sorghum	24.8	29.8	June 22—August 9	1909	0.55	27.2
	Winfield fine sand	D		Mustard	6.8	5.5	October 20—December 22	1909		
	Winfield fine sand	D		Corn	18.5	16.4	April 1—June 6	1910	0.79	29.2
	Winfield fine sand	D		Sorghum	11.7	21.9	June 18—August 16	1910	0.79	29.2
1126	Winfield fine sand, subsoil	S	109	Corn	25.0	26.2	October 20—December 22	1909	0.35	8.2
	Winfield fine sand, subsoil	T		Sorghum	20.4	17.5	April 30—June 23	1908	1.50	75.0
	Winfield fine sand, subsoil	D		Corn	17.7	26.6	June 22—August 9	1909	0.62	25.2
	Winfield fine sand, subsoil	D		Sorghum	2.5	3.9	April 1—June 6	1910	0.99	35.2
1133	Norfolk fine sand	T	138	Corn	25.8	15.9	June 18—August 16	1910	0.81	4.0

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS—continued.

GROUP 3—100-150 PARTS PER MILLION ACTIVE POTASH—continued.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams. P N	Weight of Crop Per Pot Grams. P N K	Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
	Norfolk fine sand	S		Mustard	5.1	5.0	April 27—June 16	1908	0.92	47.4
	Norfolk fine sand	D		Sorghum	16.1	26.0	October 15—December 18	1908	1.84	18.8
1139	Lufkin fine sandy loam	D	108	Corn	37.0	44.0	June 22—August 6	1909	0.70	22.6
	Lufkin fine sandy loam	D		Mustard	3.0	4.4	April 27—June 16	1908	1.63	113.3
	Lufkin fine sandy loam	D		Sorghum	20.0	28.3	October 22—December 18	1908	1.34	8.0
1588	Lufkin sandy loam	S	102	Mustard	8.4	8.7	June 22—August 6	1909	0.40	16.0
	Lufkin sandy loam	D		Sorghum	21.4	24.3	September 15—November 3	1908	2.08	35.0
	Lufkin sandy loam	T		Kafir	12.0	9.8	June 24—August 10	1909		
	Lufkin sandy loam	T		Mustard	4.7	1.5	August 16—October 4	1909	1.12	26.8
	Lufkin sandy loam	D		Corn	16.0	26.3	October 20—December 22	1909	1.06	10.0
	Lufkin sandy loam	DD		Sorghum	1.5	7.9	April 1—June 6	1910	1.17	36.0
1589	Lufkin sandy loam, subsoil	T	134	Mustard	5.8	5.1	June 18—August 16	1910	1.18	3.6
	Lufkin sandy loam, subsoil	S		Sorghum	22.4	21.9	September 15—November 3	1908		
	Lufkin sandy loam, subsoil	D		Kafir	7.3	8.4	June 24—August 10	1909		
1598	Yazoo sandy loam	S	130.0	Mustard	8.3	9.0	August 16—October 4	1909		
	Yazoo sandy loam	S		Sorghum	17.6	18.2	June 24—August 20	1909		
	Yazoo sandy loam	S		Kafir	9.2	10.0	August 16—October 4	1909		
2342	Lufkin fine sandy loam	S	132	Corn	49.0	50.0	April 1—June 6	1910	1.14	111.8
	Lufkin fine sandy loam	D		Sorghum	32.5	40.9	June 28—August 20	1910	0.45	29.2
332	Houston clay	S	140	Oats	15.5	14.5		1906		
821	Orangeburg fine sand	T	111.2	Corn	18.2	10.8	April 6—July 6	1907		
	Orangeburg fine sand	DD		Corn	1.4	5.0	September 11—November 2	1907		
	Orangeburg fine sand	DD		Corn	2.9	7.2	May 11—August 5	1908	2.12	12.2
	Orangeburg fine sand	D		Mustard	1.3	1.5	October 16—December 14	1908		
	Orangeburg fine sand	D		Sorghum	4.4	8.4	June 22—August 9	1909		
1932	Calcasieu fine sandy loam, subsoil	S	124	Corn	22.8	22.6	May 12—June 18	1909	1.73	78.8
	Calcasieu fine sandy loam, subsoil	D		Sorghum	11.4	19.1	August 5—September 21	1909	1.32	28.0
1956	Sandy soil	D	106	Corn	21.0	27.3	March 16—May 13	1909	1.11	46.6
	Sandy soil	DD		Sorghum	6.4	14.3	August 10—September 28	1909	1.73	22.2
	Sandy soil	D		Mustard	2.5	2.9	October 16—December 22	1909		
	Sandy soil	D		Corn	13.0	15.0	April 1—June 6	1910	1.17	30.4
	Sandy soil	S		Sorghum	20.7	19.5	June 18—August 16	1910	0.72	29.8
2824	Orangeburg fine sandy loam	D	105	Corn	26.3	38.5	April 1—June 6	1910	1.62	85.2
	Orangeburg fine sandy loam	D		June corn	18.7	25.8	July 19—August 31	1910	0.24	9.0
2341	Franklin clay, subsoil	D	139	Mustard	1.9	4.0	November 12—December 22	1909		
	Franklin clay, subsoil	D		Corn	30.0	37.0	April 1—June 6	1910	1.56	93.2
	Franklin clay, subsoil	S		Sorghum	27.7	28.9	June 28—August 20	1910	0.72	40.0

2347	Susquehana gravelly loam, subsoil	S	148	Mustard	3.2	3.0	November 9—December 22	1909		
	Susquehana gravelly loam, subsoil	S		Corn	27.1	25.2	April 1—June 3	1910	1.58	85.4
	Susquehana gravelly loam, subsoil	S		Sorghum	22.2	24.5	June 28—August 24	1910	0.72	32.0
2352	Norfolk fine sand	D	122	Mustard	6.0	6.8	November 9—December 22	1909		
	Norfolk fine sand	S		Corn	38.2	36.5	April 1—June 3	1910	1.10	84.0
	Norfolk fine sand	D		June corn	15.2	25.2	July 19—September 1	1910	0.57	17.4
2410	Black subsoil, Jefferson county	DD	112	Mustard	1.9	4.2	November 12—December 22	1909	1.23	4.6
	Black subsoil, Jefferson county	D		June corn	4.0	7.0	July 19—August 16	1910	1.18	9.4
	Black subsoil, Jefferson county	S		Corn	38.5	36.0	April 1—June 3	1910	1.42	87.4
342	Orangeburg fine sand	T	120	Oats	12.0	10.5		1907		
176	Norfolk fine sandy loam	S	104	Cowpeas	20.7	19.5	May 31—August 4	1905		
174	Norfolk fine sand	D	145	Cowpeas	19.6	22.0	May 31—August 4	1905		
3332	Travis gravel	S	125.9	Sorghum	46.9	50.5	June 27—August 24	1910	1.88	176.2
1134	Norfolk fine sand, subsoil	D	149	Corn	22.9	29.4	April 30—June 23	1908	3.60	164.8
	Norfolk fine sand, subsoil	D		Mustard	5.3	6.6	October 27—December 18	1908	1.00	10.6
	Norfolk fine sand, subsoil	D		Sorghum	17.1	22.7	June 22—August 6	1909	0.50	17.2
1140	Lufkin fine sandy loam	DD	102	Corn	3.0	45.5	April 30—June 23	1908		
2825	Orangeburg fine sandy loam	T	123	Mustard	5.5	3.6	November 9—December 22	1909		
	Orangeburg fine sandy loam	D		Corn	27.5	34.0	April 1—June 7	1910	1.23	67.6
	Orangeburg fine sandy loam	D		June corn	21.2	27.7	July 19—August 31	1910	0.74	31.4

GROUP 4—150-200 PARTS PER MILLION ACTIVE POTASH.

1931	Calcasieu fine sandy loam	D	170	Corn	10.8	20.6	May 12—June 18	1909	3.26	70.0
	Calcasieu fine sandy loam	D		Sorghum	23.0	32.9	August 5—September 21	1909	0.85	39.2
135	Norfolk sand	S	193	Cotton	19.3	18.2	July 8—September 10	1905		
180	Orangeburg fine sandy loam	S	162	Cowpeas	20.1	21.4	May 31—August 4	1905		
310	Orangeburg fine sandy loam	S	164	Corn	5.6	6.1		1906		
	Orangeburg fine sandy loam	T		Cowpeas	6.1	4.0		1906		
	Orangeburg fine sandy loam	D		Oats	3.2	5.0		1906		
	Orangeburg fine sandy loam	D		Corn	33.3	37.0		1908	0.67	44.6
336	Susquehana fine sandy loam	D	193	Corn	12.0	20.1	July 19—September 3	1906	1.89	28.0
340	Susquehana fine sandy loam	D	167	Corn	7.1	12.0	July 19—September 3	1906	8.25	45.0
	Susquehana fine sandy loam	T		Oats	6.0	4.0		1907		
	Susquehana fine sandy loam	D		Grass	0.3	1.3	February 6—May 8	1908		
344	Orangeburg fine sandy loam	T	175	Oats	5.5	4.0		1906		
850	Susquehana sandy loam	S	181	Corn	17.5	18.0	May 12—June 18	1909	4.04	141.4
1122	Hagensport loam, subsoil	DD	158	Corn	2.4	24.3	April 30—June 23	1908		
1124	Winfield fine sandy loam, subsoil	T	178	Corn	23.0	21.0	April 30—June 23	1908	2.40	110.4
	Winfield fine sandy loam, subsoil	S		Mustard	7.0	4.6	October 22—December 18	1908	2.18	50.6
1136	Norfolk fine sandy loam	D	177	Corn	20.0	23.0	April 30—June 23	1908		
1138	Susquehana fine sandy loam	S	151	Corn	22.0	20.2	April 30—June 23	1908	2.65	116.6
	Susquehana fine sandy loam	S		Mustard	0.4	0.5	October 22—December 18	1908		
	Susquehana fine sandy loam	D		Sorghum	14.0	18.5	June 22—August 9	1909	1.77	49.6
	Susquehana fine sandy loam	D		Corn	22.3	27.4	April 1—June 6	1910	1.02	45.4
	Susquehana fine sandy loam	DD		Sorghum	3.0	6.4	June 18—August 16	1910	1.26	7.6

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS—continued.

GROUP 4—150-200 PARTS PER MILLION ACTIVE POTASH—continued.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams.		Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
					P N	P N K				
1577	San Antonio clay loam	S	162	Mustard	11.3	11.9	September 15—November 3	1908	-------	-------
	San Antonio clay loam	S	-------	Sorghum	14.3	15.7	June 24—August 10	1909	-------	-------
	San Antonio clay loam	S	-------	Kafir	4.0	4.1	August 16—October 4	1909	-------	-------
	San Antonio clay loam	T	-------	Mustard	5.5	3.7	October 20—December 22	1909	2.46	29.0
1595	Austin clay	S	159	Mustard	10.1	9.9	September 15—November 3	1908	-------	-------
	Austin clay	D	-------	Corn	14.2	18.3	March 16—May 13	1909	1.18	33.6
	Austin clay	S	-------	Sorghum	18.2	21.2	August 10—September 24	1909	-------	-------
1597	Yazoo sandy loam	S	164	Mustard	10.6	10.4	September 15—November 3	1908	-------	-------
	Yazoo sandy loam	S	-------	Sorghum	17.7	17.4	June 24—August 10	1909	-------	-------
	Yazoo sandy loam	T	-------	Mustard	7.1	0.1	October 20—December 22	1909	2.82	40.0
	Yazoo sandy loam	T	-------	Sorghum	13.7	7.2	July 19—August 16	1910	2.61	71.0
1930	Yazoo clay, subsoil	T	184	Corn	11.8	8.1	May 12—June 28	1909	-------	-------
	Yazoo clay, subsoil	S	-------	Sorghum	26.7	29.4	August 5—September 21	1909	-------	-------
1933	Sharkey clay	D	-------	Corn	17.5	14.8	May 12—June 18	1909	2.81	98.4
1936	Houston black clay, subsoil	T	173	Corn	39.4	32.1	May 12—July 13	1909	3.21	235.4
	Houston black clay, subsoil	T	-------	Sorghum	26.5	22.3	August 10—September 21	1909	2.50	132.6
	Houston black clay, subsoil	S	-------	Mustard	12.2	13.3	October 14—December 22	1909	2.52	61.4
	Houston black clay, subsoil	S	-------	Corn	34.0	34.2	April 1—June 6	1910	1.82	123.8
	Houston black clay, subsoil	T	-------	Sorghum	49.5	42.2	June 18—August 16	1910	1.31	129.6
1120	Susquehana fine sand, subsoil	S	175	Corn	13.5	13.0	April 30—June 23	1908	-------	-------
	Susquehana fine sand, subsoil	S	-------	Mustard	4.6	5.1	October 22—December 18	1908	3.06	28.2
	Susquehana fine sand, subsoil	D	-------	Sorghum	22.7	27.3	June 22—August 6	1909	-------	-------
2830	Denison clay loam	D	151	Corn	37.7	45.5	April 1—June 6	1910	1.82	123.8
	Denison clay loam	D	-------	June corn	15.9	22.7	July 19—August 31	1910	0.49	15.6
2822	Sherman loam	S	183	Mustard	2.2	2.4	November 9—December 2	1909	-------	-------
	Sherman loam	D	-------	Corn	36.5	41.7	April 1—June 2	1910	2.14	156.2
	Sherman loam	D	-------	June corn	18.3	22.0	July 1—September 1	1910	1.01	37.0
829	Houston loam	S	174	Corn	32.5	31.4	April 17—June 19	1907	2.30	249.6
	Houston loam	D	-------	Corn	2.8	5.0	September 11—November 12	1907	-------	-------
	Houston loam	S	-------	Grass	7.1	7.2	January 28—June 3	1908	-------	-------
2831	Denison clay loam	S	189	Mustard	2.6	2.8	November 22—January 10	1909	1.17	6.0
	Denison clay, loam	S	-------	Corn	39.0	42.0	April 1—June 6	1910	1.24	96.8
	Denison clay loam	D	-------	Sorghum	10.2	15.3	July 19—August 31	1910	0.62	12.6
2944	Houston black clay loam	S	175	Corn	43.6	43.0	April 1—June 3	1910	1.70	148.2
	Houston black clay loam	S	-------	Sorghum	41.4	44.7	June 2—August 24	1910	0.70	58.0
2947	Houston black clay, subsoil	D	180	Corn	21.0	34.5	April 1—June 7	1910	1.89	79.4
	Houston black clay, subsoil	D	-------	June corn	9.3	14.2	July 19—August 31	1910	1.73	32.2
110	Houston black clay	S	176	Cotton	5.4	5.3	July 22—September 10	1905	-------	-------
330	Crawford stony clay	D	198	Corn	17.0	19.8	July 19—September 3	1907	4.42	165.9

	Crawford stony clay	S		Oats	6.5	6.9		1907		
3663	Orangeburg clay	S	168	June corn	22.2	20.2	July 19—September 1	1910	1.74	79.4
	Orangeburg clay	D		Mustard	2.2	3.3		1910		

GROUP 5—200-300 PARTS PER MILLION ACTIVE POTASH.

3662	Orangeburg clay	S	242	June corn	26.0	24.5	July 19—September 1	1910	2.74	194.4
2340	Franklin clay	T	278	Mustard	3.5	1.5	November 9—December 22	1909	3.94	27.6
	Franklin clay	T		Corn	50.0	41.5	April 1—June 7	1910	2.26	226.0
	Franklin clay	S		Sorghum	45.7	44.7	June 28—August 24	1910	1.15	105.2
133	Sanders loam	D	230	Corn	9.1	11.9		1906		
	Sanders loam	D		Oats	6.5	10.2		1906		
129	Lufkin clay	D	221	Cotton	2.7	3.3		1905		
324	Houston black clay	D	281	Corn	12.8	16.1	July 19—September 3	1906		
	Houston black clay	T		Oats	10.0	2.5		1907		
913	Susquehana fine sandy loam	D	283	Corn	3.7	6.4	September 7—November 12	1907		
1119	Susquehana fine sand	S	207	Corn	32.7	35.6	April 27—June 16	1908	2.30	152.4
	Susquehana fine sand	S		Mustard	6.6	6.9	October 22—December 18	1908	1.60	21.2
	Susquehana fine sand	D		Sorghum	15.8	25.9	June 22—August 6	1909	0.65	20.6
3633	Houston black clay	T	264	Sorghum	22.5	18.1	June 27—August 11	1910	2.95	132.8
	Houston black clay	T		Mustard	5.0	1.8		1910		
2346	Susquehana gravelly loam	S	224	Corn	46.0	45.6	April 1—June 3	1910	4.94	434.6
	Susquehana gravely loam	D		June corn	5.5	7.9	July 19—August 16	1910	1.59	17.4
3634	Houston black clay	D	251	Sorghum	8.2	10.2	July 9—August 25	1910	3.44	56.4
982	Cameron clay, subsoil	D	268	Corn	41.1	50.9	May 7—June 23	1908	3.68	302.6
	Camerson clay, subsoil	D		Mustard	6.9	8.1	October 22—December 18	1908	3.80	51.6
1123	Winfield fine sandy loam	D	230	Corn	18.9	27.7	April 27—June 16	1908	3.58	136.0
	Winfield fine sandy loam	T		Mustard	9.7	8.2	October 22—December 18	1908	2.48	48.2
1127	Houston clay	T	251	Corn	46.2	39.3		1908		
1205	Houston loam, subsoil	T	241	Corn	33.6	16.0	May 7—June 23	1908	2.02	135.8
	Houston loam, subsoil	D		Mustard	6.2	10.2	October 22—December 18	1908	2.38	29.8
1207	Nueces fine sandy loam	T	252	Corn	42.7	26.0	May 7—June 23	1908	2.18	186.2
	Nueces fine sandy loam	D		Mustard	4.3	6.4	October 22—December 18	1908	2.53	21.8
	Nueces fine sandy loam	D		Sorghum	12.2	16.6	June 22—August 6	1909	1.36	33.2
1583	Houston gravelly clay, subsoil	S	212	Mustard	9.5	7.2	September 15—November 3	1908	1.54	28.6
1926	Yazoo sandy loam, subsoil	T	210	Corn	16.3	10.8	May 12—June 28	1909	5.01	163.0
1928	Peach Ridge, subsoil	S	270	Corn	7.8	7.6	May 12—June 18	1909	5.62	87.6
	Peach Ridge, subsoil	T		Sorghum	30.6	23.7	August 5—September 21	1909	2.08	163.2
1934	Sharkey clay, subsoil	D	267	Corn	18.4	29.2	May 12—June 18	1909	3.64	134.0
1935	Houston black clay	S	246.5	Corn	27.2	27.7	May 12—June 18	1909	3.00	163.2
2829	Dawson clay	S	233	Corn	18.0	16.5	April 1—June 6	1910	4.17	150.2
	Dawson clay	S		June corn	10.5	11.7	July 19—September 1	1910	2.10	44.2
3331	Travis gravel	S	223	Sorghum	47.0	50.4	June 27—August 24	1910	0.98	92.2
3339	Crawford loam	S	280	Sorghum	60.5	60.5	June 27—August 24	1910	1.44	163.4
3340	Crawford loam, subsoil	S	246	Sorghum	57.4	62.6	June 27—August 24	1910	1.00	114.8
3346	Susquehana fine sandy loam	S	273	Sorghum	40.7	40.5	June 27—August 20	1910	2.50	208.6
127	Houston black clay	S	230	Corn	12.2	12.0		1906		
	Houston black clay	S		Cowpeas	13.6	13.2		1906		
	Houston black clay	D		Oats	7.5	9.2		1906		

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS—continued.

GROUP 5—200-300 PARTS PER MILLION ACTIVE POTASH—continued.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams.		Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
					P N	P N K				
306	Susquehana fine sandy loam	T	210	Corn	12.4	10.9		1906		
	Susquehana fine sandy loam	D		Cowpeas	9.3	8.4		1906		
334	Houston loam	S	287	Corn	13.0	10.2	July 19—September 3	1906	1.34	37.8
	Houston loam	T		Oats	10.0	8.5		1907		
816	Laredo fine sand	T	218	Corn	22.2	16.2	April 6—June 11	1907		
	Laredo fine sand	T		Corn	6.4	3.4		1907		
	Laredo fine sand	S		Grass	5.9	6.2	January 28—June 3	1908		
	Laredo fine sand	D		Mustard	9.4	10.8		1908		
	Laredo fine sand	D		Sorghum	22.2	25.0	June 22—August 6	1909	3.71	69.8
818	Sanders loam	S	274	Corn	43.3	43.1	April 6—June 17	1907		
	Sanders loam	D		Corn	4.1	6.6	September 10—December 11	1907	2.92	253.0
832	Orangeburg fine sandy loam	D	271	Corn	16.8	26.2	April 17—June 14	1907		
	Orangeburg fine sandy loam	T		Corn	2.1	1.4		1907	9.57	321.6
937	Susquehana fine sandy loam	D	270	Corn	6.9	8.4	September 7—November 12	1907		
938	Austin fine sandy loam	D	276	Corn	6.3	8.8	September 7—November 12	1907		
	Austin fine sandy loam	D		Wheat	1.1	3.0	February 6—May 8	1908		
	Austin fine sandy loam	T		Corn	48.5	40.4	May 11—August 5	1908		
	Austin fine sandy loam	D		Mustard	5.0	6.5	October 16—December 14	1908		
	Austin fine sandy loam	T		Kafir	4.6	1.3	August 16—October 14	1909	5.75	57.5
	Austin fine sandy loam	T		Sorghum	17.9	10.7	June 24—August 10	1909		
	Austin fine sandy loam	T		Sorghum	12.9	2.4	June 1—August 16	1910	0.96	24.8

GROUP 6—300-400 PARTS PER MILLION ACTIVE POTASH.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	P N	P N K	Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
936	Barton sandy loam	D	326	Corn	10.0	11.3	May 11—August 5	1908		
1131	Wabash clay	T	366	Corn	56.5	47.8	April 30—June 23	1908	3.18	354.8
	Wabash clay	D		Mustard	11.2	13.2	October 22—December 18	1908		
1204	Houston loam	T	312	Corn	21.9	14.4	April 30—June 23	1908	3.21	140.6
	Houston loam	S		Mustard	7.7	7.7	October 22—December 18	1908	2.14	32.2
1206	Nueces fine sandy loam	D	363	Corn	16.0	19.9	April 30—June 23	1908	3.39	108.8
1581	Houston black clay loam	S	315	Mustard	9.7	9.9	September 15—November 3	1908	1.79	34.8
	Houston black clay loam	T		Sorghum	24.8	20.7	June 24—August 10	1909		
1593	Houston black clay	S	321	Mustard	12.6	12.0	September 15—November 2	1908		
	Houston black clay	D		Corn	17.3	20.7	March 16—May 13	1909	4.10	141.8
1600	Houston black clay, subsoil	S	348	Mustard	12.4	11.1	September 15—November 2	1908		
	Houston black clay, subsoil	S		Sorghum	25.7	27.9	June 24—August 24	1909		
	Houston black clay, subsoil	T		Kafir	15.4	13.1	August 16—October 4	1909		

2046	Houston black clay	D	379	Corn	20.0	24.1	April 1—May 21	1910	1.66	66.4
	Houston black clay	T		Sorghum	51.7	45.2	June 28—August 24	1910	1.69	175.2
833	Laredo fine sandy loam	D	331	Corn	24.8	29.0	April 17—June 11	1907	5.89	292.2
	Laredo fine sandy loam	T		Corn	6.7	2.2	September 12—November 12	1908		
	Laredo fine sandy loam	S		Grass	5.7	5.9	January 28—June 3	1908		
851	Wilson clay loam	D	388	Corn	19.2	23.4	May 1—June 19	1907	5.80	222.8
	Wilson clay loam	D		Grass	3.8	4.5	March 27—June 3	1908		
914	Lufkin fine sandy loam	D	326	Corn	7.8	10.9	September 7—November 12	1907		
	Lufkin fine sandy loam	T		Sorghum	21.0	8.0	June 24—August 13	1909		
938	Austin fine sandy loam	D	339	Corn	6.7	8.2	April 1—June 6	1910	1.32	17.6
3631	Lufkin fine sandy loam	S	309	Sorghum	47.9	50.9	June 27—August 24	1910	1.92	184.0
	Lufkin fine sandy loam	S		Mustard	4.3	4.8		1910		
3632	Lufkin sandy loam	S	320	Sorghum	42.9	45.3	June 27—August 24	1910	2.44	209.4
	Lufkin sandy loam	T		Mustard	4.5	2.2		1910		
1927	Peach Ridge soil	D	312	Corn	26.1	30.3	May 12—June 18	1909	4.06	212.0
	Peach Ridge soil	D		Sorghum	12.8	14.4		1909		
	Peach Ridge soil	S		Sorghum	52.9	52.9	June 18—August 16	1910	1.37	145.0
2343	Lufkin fine sandy loam, subsoil	S	301	Corn	37.1	40.5	April 1—June 3	1910	1.12	83.2
	Lufkin fine sandy loam, subsoil	D		Sorghum	31.7	42.4	June 18—August 24	1910	0.80	50.8
178	Orangeburg clay	D	376	Cowpeas	20.1	24.3	May 31—August 4	1905		
3337	Miller fine sandy loam	S	309	June corn	26.7	24.7	July 9—August 24	1910	3.50	186.8
3345	Susquehana fine sandy loam	D	318	Sorghum	41.5	55.5	June 27—August 24	1910	2.11	175.2
933	Bastrop clay	T	307	Corn	5.7	3.1	September 7—November 12	1907		
	Bastrop clay	D		Grass	3.5	5.5	January 28—June 3	1908		
	Bastrop clay	S		Mustard	16.8	15.9	October 16—December 14	1908	6.46	217.0
	Bastrop clay	S		Sorghum	20.1	22.5		1909		
2828	Denison clay	T	308	Corn	28.5	25.5	April 1—June 3	1910	4.46	254.2
	Denison clay	T		June corn	19.0	16.2	July 19—September 1	1910	1.90	72.2
128	Norfolk silt loam	D	396	Cotton	4.2	4.9	July 15—August 17	1905		
134	San Antonio clay loam	D	376	Corn	6.9	9.5		1906		
	San Antonio clay loam	S		Oats	8.5	8.3		1906		
834	Orangeburg fine sandy loam	T	310	Corn	27.7	24.6	April 7—June 14	1907	4.19	229.4
934	Wabash clay	D	341	Corn	4.1	5.6	September 7—November 12	1907		
	Wabash clay	D		Grass	3.5	5.1	January 28—June 3	1908		

GROUP 7—400-600 PARTS PER MILLION ACTIVE POTASH.

182	Yazoo clay	D	417	Corn	2.6	3.6		1906		
	Yazoo clay	S		Cowpeas	4.1	4.4		1906		
	Yazoo clay	S		Grass	1.3	1.1	March 27—June 3	1908		
	Yazoo clay	S		Mustard	18.5	18.2	October 16—December 14	1908	3.47	108.4
940	Wilson loam	T	513	Corn	10.0	6.7	September 7—November 12	1907		
	Wilson loam	S		Grass	5.5	5.0	February 6—May 8	1908		
	Wilson loam	T		Mustard	14.4	10.1	October 22—December 18	1908	5.17	149.0
	Wilson loam	T		Sorghum	31.4	10.0	June 22—August 9	1909		
1121	Hagensport loam	DD	464	Corn	15.7	48.7	April 27—June 16	1908	5.71	121.0
	Hagensport loam	S		Mustard	2.7	2.6	October 22—December 18	1908	6.01	32.4
	Hagensport loam	T		Sorghum	11.2	6.3		1909		
	Hagensport loam	T		Sorghum	34.7	40.8	June 10—August 16	1910	0.69	47.8

TABLE 9—ACTIVE SOIL POTASH AND POT EXPERIMENTS—continued.

GROUP 7—400-600 PARTS PER MILLION ACTIVE POTASH—continued.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	Weight of Crop Per Pot Grams.		Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
					P N	P N K				
1582	Houston gravelly clay	S	447	Mustard	8.9	9.9	September 15—November 3	1908	3.72	66.2
	Houston gravelly clay	S		Sorghum	28.3	27.0	June 24—August 10	1909		
	Houston gravelly clay	D		Kafir	14.2	16.1	August 24—October 4	1909		
1599	Houston black clay	S	547	Mustard	13.8	13.0	September 15—November 3	1908		
	Houston black clay	T		Corn	20.2	18.4	March 16—May 13	1909	4.63	187.0
	Houston black clay	S		Kafir	24.5	22.8	August 10—September 28	1909		
1925	Yazoo sandy loam	S	421	Corn	40.4	43.8	May 12—June 18	1909	3.66	295.8
1929	Yazoo clay	T	491	Corn	36.6	32.9	May 12—July 13	1909	3.36	246.0
	Yazoo clay	S		Sorghum	28.2	26.3	August 10—September 21	1909	2.76	155.6
	Yazoo clay	T		Mustard	12.6	7.6	October 14—December 27	1909	2.12	53.4
	Yazoo clay	T		Corn	42.5	38.5	April 1—June 6	1910	1.77	150.4
827	Laredo silt loam	T	442	Corn	20.5	15.5	April 6—June 11	1907		
	Laredo silt loam	T		Corn	3.6	2.9	September 11—November 12	1907		
	Laredo silt loam	T		Grass	4.5	3.5	January 28—June 3	1908		
	Laredo silt loam	S		Mustard	6.8	7.5	October 22—December 18	1908	4.73	64.4
	Laredo silt loam	S		Sorghum	13.1	13.3	June 22—August 6	1909		
	Laredo silt loam	T		Sorghum	2.8	1.9	August 24—October 4	1909	3.86	21.6
	Laredo silt loam	T		Mustard	3.5	0.2	October 20—December 22	1909		
2957	Subsoil from Mercedes, Texas	T	500	Mustard	9.0	5.3		1909	4.16	74.8
	Subsoil from Mercedes, Texas	D		Corn	30.0	38.6	April 1—June 3	1910	3.12	187.2
	Subsoil from Mercedes, Texas	D		June corn	13.9	21.7	July 19—August 31	1910	2.56	69.2

GROUP 8—600-800 PARTS PER MILLION ACTIVE POTASH.

Laboratory No.	Name of Soil.	Deficiency.	Active Potash Per Million of Soil.	Name of Crop.	P N	P N K	Period of Growth.	Year.	Percentage Potash in P N Crops.	Potash Removed by Crop in Parts Per Million of Soil.
830	Laredo gravelly loam	T	605	Corn	17.5	5.0	April 17—June 6	1907	7.06	247.2
845	Sanders silt loam	S	735	Corn	27.2	29.2	May 7—June 19	1907	7.00	380.8
1202	Houston clay	T	736	Corn	38.4	36.0	April 30—June 23	1908	4.40	338.0
	Houston clay	S		Mustard	6.5	6.6	October 22—December 18	1908		
1203	Houston clay, subsoil	T	601	Corn	41.1	29.7	May 7—June 23	1908	2.35	193.2
	Houston clay, subsoil	D		Mustard	5.9	6.8	October 22—December 18	1908	3.35	8.0
1580	Houston black clay loam	S	657	Mustard	10.8	11.0	September 15—November 3	1908	0.60	13.0
	Houston black clay loam	S		Sorghum	26.4	26.0	June 24—August 10	1909		
	Houston black clay loam	D		Mustard	2.2	6.5	October 21—December 22	1909		
	Houston black clay loam	T		Corn	36.5	33.0	April 1—June 6	1910	3.21	238.4
	Houston black clay loam	S		Sorghum	40.0	40.0	June 18—August 16	1910	1.79	143.2
912	Bastrop sandy loam	D	695	Corn	1.0	4.2	September 7—November 12	1907		
	Bastrop sandy loam	T		Corn	68.4	47.7	May 11—August 5	1908	2.45	337.2

2956	Fertile soil	T	629	Mustard	7.8	5.0	November 12—February 10	1909	4.91	76.6
	Fertile soil	S		Corn	44.0	43.0	April 1—June 3	1910	3.70	325.6
	Fertile soil	T		June corn	29.4	18.3	July 19—August 31	1910	3.08	181.0

GROUP 9—800-1000 PARTS PER MILLION ACTIVE POTASH.

1579	Norfolk silt loam	S	887	Mustard	11.0	10.2	September 15—November 2	1908		
	Norfolk silt loam	S		Corn	21.5	21.3	March 16—May 13	1909	5.39	231.8
	Norfolk silt loam	T		Sorghum	10.9	9.1	August 17—September 28	1909		

TABLE 10—NUMBER OF DEFICIENT CROPS IN GROUPS ARRANGED ACCORDING TO ACTIVE POTASH.

Group Number.	Active Potash in Soils in Parts Per Million.	Number of Crops.				No. of Soils.	Percentage of Crops.				
		DD	D	S	T		DD	D	S	T	DD and D
1	0—50	1	12	1	1	5	6.7	80.0	6.7	6.7	86.7
2	50—100	12	31	22	13	33	15.4	39.7	28.2	16.7	55.1
3	100—150	7	37	24	13	31	8.6	45.7	29.6	16.1	54.3
4	150—200	1	24	28	11	28	1.6	37.5	43.8	17.2	39.1
5	200—300	0	24	20	20	33	0.0	37.5	31.3	31.3	37.5
6	300—400	0	20	15	12	25	0.0	42.6	31.9	25.5	42.6
7	400—600	1	4	13	15	9	3.0	12.0	39.4	45.6	15.0
8	600—800	0	3	6	7	7	0.0	18.6	37.5	43.8	18.0
9	800—1000	0	0	2	1	1	0.0	0.0	66.7	33.3	0.0

On examination of the table, we find a total of 22 crops of the 403 which are very deficient, and these are found mostly in the first three groups, containing 0-150 parts per million of potash. The percentage of very deficient crops is irregular, but there is only one very deficient crop each in groups 1, 4, and 7. There are 12 very deficient crops in group 2, and 7 in group 3, but we must remember some of these crops were second or third or later crops, and, as we shall see, the active potash is removed rather rapidly from the soil in pot experiments.

Taking the deficient and very deficient crops together, we find a regular decrease in percentage, from 86.7 per cent in group 1, to 0 in group 9, the only exception being group 6, which is a little higher than the groups preceding it.

In this connection, we must observe that a number of these crops represent second, third or fourth crops, and the preceding crops have already removed some of the active potash from the soil. Thus the active potash actually present at the time of growing these later crops is less than as represented in the table. This would affect the soils containing from 100 to 300 parts per million of potash more than those containing greater quantities of potash, since the active potash is more rapidly exhausted from the former.

The soils seem to fall naturally into four groups as regards number of deficient and very deficient crops.

Group 1—0 to 50 parts potash, 86.7 per cent deficient.

Groups 2-3—50 to 150 parts potash, 55.1-54.3 per cent deficient.

Groups 4-5-6—150 to 400 parts potash, 39.1-42.6 per cent deficient.

Groups 7-8—400 to 800 parts potash, 15-18 per cent deficient.

Group 9 contains only 3 crops on 1 soil, so it is left out.

Crops marked T produced a greater yield when no potash was added. The percentages of the crops actually injured by potash increases somewhat irregularly with the potash content of the soil, from 6.7 per cent in the first group, to 45.6 in group 7.

The percentages of deficient crops decrease with the quantity of active potash in the soil.

The percentage of crops injured by potash increases with the quantity of active potash in the soil.

TABLE 11—AVERAGE WEIGHT OF ALL CROPS WITH AND WITHOUT POTASH.

Group Number.	Potash in Soils in Parts Per Million.	Number Averaged.	Average Weight in Grams.		Percentage.	Maximum Weight.	Crop.
			PN.	PNK.	PN/PNK.	PN.	
1	0—50	15	10.9	16.4	67	32.2	Sorghum.
2	50—100	78	11.3	14.3	79	43.0	Sorghum.
3	100—150	81	14.8	17.5	84	49.0	Corn.
4	150—200	65	16.0	17.5	91	43.6	Corn.
5	200—300	64	18.6	18.6	100	60.5	Sorghum.
6	300—400	48	19.3	19.7	98	56.5	Corn.
7	400—600	33	16.1	15.9	101	42.5	Corn.
8	600—800	16	25.2	21.8	116	68.4	Corn.
9	800—1000	3	14.5	13.5	------	21.5	Corn.
	Total	403					

TABLE 12—WEIGHTS OF SORGHUM AND KAFIR, OF CORN AND JUNE CORN AND OF MUSTARD, ON THE SOIL.

Group Number.	Potash in Soils in Parts Per Million.	Corn and June Corn.			Sorghum and Kafir.			Mustard.		
		Number Averaged.	Average Weight in Grams.		Number Averaged.	Average Weight in Grams.		Number Averaged.	Average Weight in Grams.	
			PN.	PNK.		PN.	PNK.		PN.	PNK.
1	0—50	4	15.6	26.7	5	13.7	19.1	4	5.6	6.9
2	50—100	13	15.2	21.2	32	14.2	21.6	15	5.8	5.8
3	100—150	23	16.9	20.0	33	20.1	23.9	17	5.6	4.9
4	150—200	14	19.0	21.8	29	20.8	23.1	12	6.3	5.7
5	200—300	14	28.4	28.0	30	21.8	21.3	10	6.6	6.8
6	300—400	12	33.2	32.6	20	19.4	19.1	8	9.9	9.6
7	400—600	9	20.9	18.3	11	21.5	24.6	9	10.0	8.3
8	600—800	2	33.2	33.0	9	33.7	27.4	5	6.6	7.2
9	800—1000	1	10.9	9.1	1	21.5	21.3	1	11.0	10.2

Relation to Weight.—Table 11 shows the average weight of all crops, with and without potash. Table 12 shows the same for corn and June corn, kaffir and milo, and mustard.

As an average of all crops, the weight of the crop with potash is greater than the one without potash up to and including the fourth group, which contains 150-200 parts per million of active potash. Expressed in percentages of the crop with potash as 100, the crop without potash increases from 67 to 91 per cent in three groups. In group 5 it is 100 per cent. That is to say, in these pot experiments, after the soil contained 200 parts per million of active potash, the addition of potash to the soil did not, on an average, increase the growth of the plant.

The same result is reached when we consider the corn and June corn, and the milo and kaffir, averaged separately. Up to 200 parts per million of active potash in the soil, the addition of potash causes an increase in growth of the crop on the average. Beyond 200 parts per million, the addition of potash causes no increase in the crop, or else an actual decrease.

With mustard the results are somewhat different. Only with the soils containing 0-50 parts per million of active potash is there an increase in crop due to the addition of potash. With the other groups (*except group* 8), addition of potash does not affect the crop, or else causes an actual decrease.

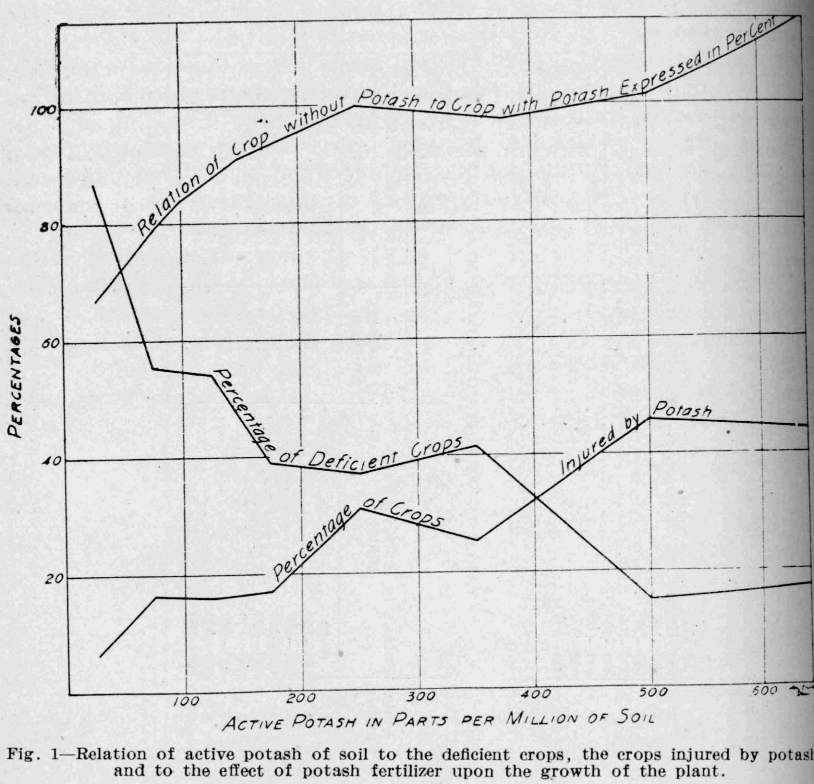

Fig. 1—Relation of active potash of soil to the deficient crops, the crops injured by potash, and to the effect of potash fertilizer upon the growth of the plant.

We can draw another conclusion from these tables. When the active potash in the soil exceeds 200 parts per million, the addition of potash no longer causes an increase in the weight of the crop. Therefore the average weight of crops (except in cases when addition of potash depresses the yield) depends upon other factors than the potash in the soil. The potash acting as a plant food is no longer the controlling factor in these pot experiments, when the active potash exceeds 200 parts per million, but the size of the crop is due to some other condition, such as the character of the soil, seasonal conditions, etc. The active potash does, however, affect the percentage of potash contained in the crop, as we shall see.

RELATION TO POTASH CONTENT OF CROP.

Potash was determined in 235 crops, and it is unfortunate that it was not estimated in all of them. The average percentage of potash in the corn or June corn, the milo and kaffir, and in the mustard crop, is presented in Table 13.

The average percentage of potash in the corn and June corn crops increases with the quantity of active potash in the soil. The average percentage in group 1 (0 to 50 parts per million of active potash) is 1.38. In group 8 (600 to 800 parts) it is 4.31.

The average percentage of potash in the sorghum and kaffir crops increases with the active potash in the soil. In group 1 (0 to 50 per million) it is 0.78 per cent, in group 7 (400 to 600) it is 2.44 per cent.

The average percentage of potash in the mustard crop is somewhat irregular, but, nevertheless, shows the same tendency to increase with the active potash content of the soil.

We thus see that though the addition of potash to the soil does not secure an average increase in weight of crop when the soil contains more than 200 parts per million of potash, yet the percentage of potash in the crop continues to increase with the active potash in the soil.

The average percentage of potash in the crops grown in the pot experiments increases as the active potash in the soil increases.

No allowance has been made in this work for the potash in the seed. This would represent approximately 20 parts per million for corn and 10 parts per million for kaffir and milo. The roots, also, are not taken into consideration.

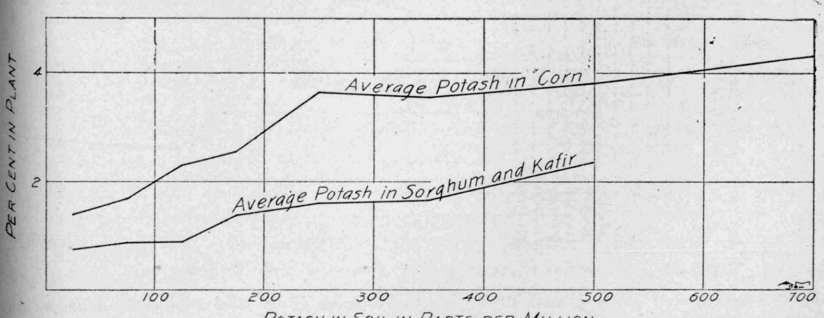

Fig. 2—Relation of the active potash in the soil to the potash content of the crops grown thereon.

TABLE 13—RELATION OF POTASH CONTENT OF PLANT TO ACTIVE POTASH OF SOIL.

Group Number.	Active Potash in Soils in Parts Per Million.	Average Potash in Parts Per Million Removed By All Crops.			Average Percentage Potash in Corn Crops.		Per Cent Potash in Sorghum and Kafir. (PN Crops.)		Per Cent Potash in Mustard. (PN Crops.)	
		Number Averaged.	Average.	Maximum.	Number Averaged.	Average.	Number Averaged.	Average.	Number Averaged.	Average.
1	0—50	11	29.3	53.4	4	1.38	4	0.78	3	2.13
2	50—100	47	37.2	143.3	16	1.70	10	0.93	13	2.05
3	100—150	50	51.0	176.2	24	2.29	15	0.89	7	1.27
4	150—200	37	80.9	249.6	19	2.55	8	1.45	6	2.37
5	200—300	37	120.1	434.6	16	3.65	11	1.68	9	3.08
6	300—400	23	156.9	354.8	12	3.53	6	1.72	3	3.47
7	400—600	17	119.4	295.8	5	3.83	3	2.44	7	4.20
8	600—800	12	206.9	380.8	7	4.31	1	1.79	3	2.95
9	800—1000	1	231.8	231.8	1	5.39	0	0.00	0	0.00

RELATION TO QUANTITY OF POTASH REMOVED FROM SOIL.

Table 14 shows the average and maximum quantity of potash removed from the soil by the various 235 crops. Full details of these results are shown in Table 9 preceding.

From an inspection of the table, it is seen immediately that *the average quantity of potash removed from the soil by the crops increases with the quantity of active potash in the soil.*

Further, the maximum quantity of potash removed by a crop in any given group increases up to the sixth group, after which it is irregular.

Group No. 7 does not fall in line with the others in this increase. On examination of the table, we find this to be due to the fact that these soils did not produce as large a crop of kaffir or sorghum, with or without potash, as the soils immediately preceding or following. This difference is probably due to conditions under which the crops were grown, or differences in the ability of the particular soils to produce heavy crops, rather than to the quantity of potash in the soil.

TABLE 14—AVERAGE POTASH IN PARTS PER MILLION REMOVED BY CORN CROPS.

Group Number.		Number Averaged.	Average.	Maximum.
1	0—50	4	34.7	53.2
2	50—100	17	57.2	143.2
3	100—150	24	78.3	164.8
4	150—200	19	110.9	235.4
5	200—300	15	192.3	321.6
6	300—400	12	177.0	354.8
7	400—600	6	197.9	295.8
8	600—800	7	294.3	380.8
9	800—1000	1	231.8	231.8

The quantity of potash removed in these pot experiments is relatively enormous. A bushel of corn requires for its production, including stalk and leaves, approximately one pound of potash. If we assume that the soil to the depth of eight inches can be drawn upon by the roots of the plant, and that this quantity represents two million pounds of soil, then one-half part potash per million is sufficient for 1 bushel of corn. The potash *actually removed* in these pot experiments by the crops grown on the soil would thus suffice for the production of the following number of bushels of corn:

TABLE 15—BUSHELS OF CORN PER ACRE EQUIVALENT TO POTASH REMOVED.

Parts Per Million of Potash in Soils.	Average.	Maximum.
0—50	58.6	106.8
50—100	74.4	286.6
100—150	102.0	352.4
150—200	161.8	499.2
200—300	240.2	869.2
300—400	313.8	719.6
400—600	238.8	591.6
600—800	413.8	761.6

That is to say, from soils containing 50 parts per million or less of active potash, plants in pot experiments removed enough potash in three months or less, for 58.6 bushels of corn, on an average. These soils, it must be remembered, were under favorable conditions

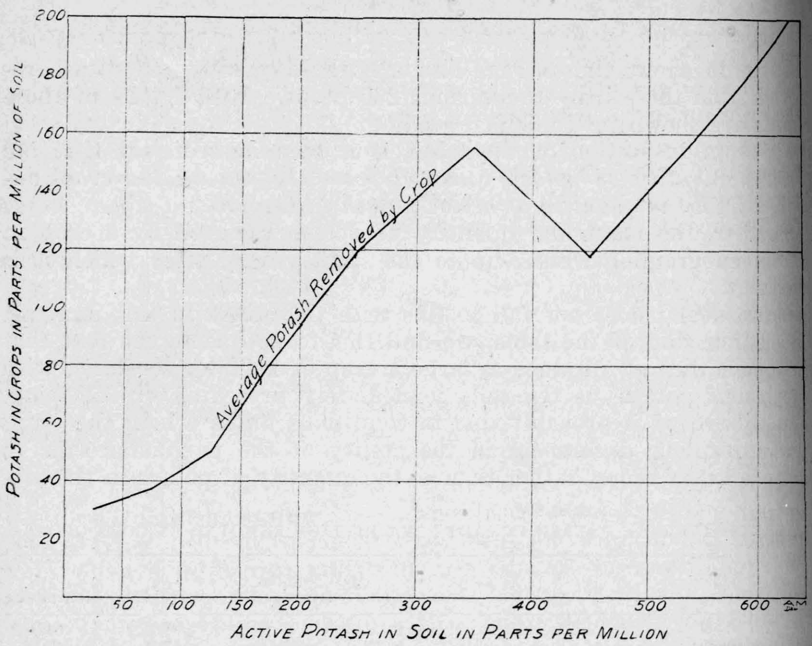

Fig. 3—Relation of the potash removed by the crops to the active potash content of the soil.

for the production of plants. They were supplied with phosphoric acid and nitrogen, and received an abundance of water. The soil was also finely pulverized and placed in good mechanical condition. The temperature in the plant houses was a little higher than in the open air.

DEFICIENCY A RELATIVE TERM.

Soil deficiency as measured by the relation between the weight of crops produced in pot experiments with KPN and with PN is a relative matter, and depends upon the maximum crop possible under the conditions of the experiment.

We have seen (Table 12) that when the active potash exceeds 200 parts per million, addition of potash no longer causes an increase in weight of the crop, on an average. The average quantity of potash removed from the soils containing 150-200 parts per million is 80.9 per million, equivalent to 161.8 bushels corn. The average corn crop on all KPN pots is 22.3 grams per pot. If we assume this corn needs 1.7 per cent potash, this would be equivalent to 76 parts per million of soil potash, or 152 bushels corn per acre.

The conditions of our pot experiments were thus favorable, on an average, to the production of dry matter equivalent to about 150 bushels of corn. If potash offered by the soil was less than this, then addition of potash caused an increase in dry matter on an average and thus the soil, on the average, was deficient.

It is thus necessary, in pot experiments, to consider not only the relative quantity of dry matter produced, but also the quantity of plant food drawn from the soil.

Thus we find:

Soils containing 0-50 parts per million of active potash are deficient in 87 per cent of the pot tests, and the average crop without potash is 67 per cent of that with potash, yet gave enough potash to the crop for 58 bushels corn per acre, on an average.

Soils containing 50-100 parts per million of active potash are deficient in 55 per cent of the pot tests and the average crop without potash is 79 per cent of that with potash, yet give up enough potash for 74 bushels corn, on an average.

Soils containing 100-150 parts per million of active potash are deficient in 55 per cent of the pot tests, and the average crop without potash is 84 per cent of that with potash, yet give up enough potash for 102 bushels of corn, average.

Soils containing 150-200 parts per million of active potash are deficient in 39 per cent of the pot tests, and the average crop without potash is 91 per cent of that with potash, yet give up enough potash on the average for 162 bushels of corn.

It is obviously a question to decide whether a soil which gives up enough potash for 58 or 74 bushels of corn is deficient or not in potash, and in applying the results of such experiments to the field one would have to consider the maximum corn crop possible under soil and climatic conditions, in order to decide whether such soil is or is not deficient. The matter of the application of these pot experiments to the field will, however, be the subject of a later bulletin.

LOSS OF ACTIVE POTASH BY THE SOIL.

In a number of our pot experiments, after growing one or more crops upon the soil, the soil in the pot was subjected to analysis. In several of these experiments, the cropping was continued until the soil was apparently deficient in potash. The object of the work was to study both the effect of cropping on the potash of the soil, and also to determine what quantity of active potash was present when the soil became decidedly deficient. Deficiency was visible not only in the growth of the plant, but also in the percentage of potash it contained, as seen in the preceding pages. The results of some of these analyses are given in Table 16. Work along this line is being continued, and further results will be published later.

TABLE 16—ACTIVE POTASH LOST FROM SOIL, IN PARTS PER MILLION.

Laboratory No.	2824	2410	2830	1933	850	1124	1928	1119	1207	2956	1925
Originally in soil	105	112	151	184	181	178	270	207	252	629	421
After cropping	71	53	96	135	69	61	169	77	131	329	276
Loss	34	59	55	49	112	117	101	130	121	300	145
Taken up by crops	94	101	162	98	141	167	251	194	241	700	296
Number of crops grown	2	3	3	1	2	2	2	3	3	4	1

It is seen by the table that there is a loss of active potash consequent upon the cropping of the soil. The loss is not equal to the potash taken up, and could not be expected to equal it, because the active potash does not represent all the easily soluble potash, but only a portion thereof. As an average of a number of these experiments, we found that the potash taken up by the plant is approximately twice the active potash lost by the soil, where the active potash exceeds 100 parts per million. Where the active potash is less than 100 parts per million, the potash taken up by the plant is about five times the loss from the soil. This could be expected since this potash represents, largely a small percentage of potash from a large quantity in highly insoluble sources.

SUMMARY AND CONCLUSIONS.

1. The potash of nephelite, leucite, glauconite, biotite is completely extracted by strong hydrochloric acid. About one-third of the potash of muscovite is extracted and only a small percentage of the potash of microcline and orthoclase.

2. Practically no potash is removed from orthoclase and microline by N/5 nitric acid, less than 10 per cent from glauconite and biotite and from 15 to 60 per cent from muscovite, nephelite, leucite, apophyllite and phillipsite.

3. Potash dissolved by N/5 nitric acid from soils represents a portion of the potash in the easily decomposed minerals.

4. From 36 to 100 per cent of the potash absorbed from aqueous solution by certain minerals was extracted by N/5 nitric acid.

5. Two per cent ammonia dissolved from 9 to 45 per cent of the potash absorbed by minerals.

6. The potash extracted represents the difference between the potash dissolved and that fixed from the solution. The fixation of potash from N/5 nitric acid is much less than the fixation of phosphoric acid from the same solvent.

7. The potash extracted from the soil by successive treatments with N/5 nitric acid at first represents easily soluble potash and is finally reduced to the small amount of potash dissolved from highly insoluble minerals.

8. Increasing the quantity of potash mineral to a fixed amount of solvent increases the quantity of potash extracted but the percentage of the potash extracted decreases.

9. The quantity of potash extracted by N/5 nitric acid below 50 parts per million represents 1 to 2 per cent of the potash of highly insoluble silicates. The quantity extracted in excess of approximately 50 parts per million represents a comparatively large percentage of a much smaller quantity of more easily soluble potash.

10. The potash extracted by N/5 nitric acid from the soil is not necessarily in the same form of combination in different soils and does not necessarily have the same value to plants.

11. A study is made of the relation between the active potash and the needs of the soil as shown in 403 pot experiments on 172 soils.

12. The percentage of crops which show an increase in growth caused by the addition of potassium fertilizers decreases from 86.7 with soils containing less than 50 parts per million of active potash to zero in soils containing 800 to 1000 parts per million of active

potash. The effect of the potash decreases with the active potash in the soil.

13. The percentage of crops injured by the potash increases with the quantity of active potash in the soil.

14. The effect of the addition of potash to the soil upon the average weight of the crop in the pot experiments decreases with the quantity of the active potash in the soil. When the soil contains more than 200 parts per million of active potash, addition of potash does not increase the average weight of the crop, but often decreases the crop.

15. The average percentage of potash contained in 235 crops increases with the percentage of active potash in the soil.

16. The average quantity of potash removed from the soil by the crops increases with the quantity of active potash in the soil.

17. Relatively enormous quantities of potash are removed by the crops in these pot experiments. Expressed in terms of bushels of corn equivalent to the potash removed, the quantity averaged 58.6 bushels in soils containing less than 50 parts per million of active potash and 413.8 bushels in soils containing 600 to 800 parts per million.

18. Deficiency of plant food is a relative term and depends upon the growth which can be made under the conditions of the experiment.

19. Soils containing less than 50 parts per million of active potash were deficient in 87 per cent of the pot tests and the average crop without potash is 67 per cent of that with potash, and yet these soils gave up enough potash to the crop to produce 58 bushels corn to the acre, on the average.

20. There is a loss of active potash consequent upon the cropping of the soil. The loss is approximately one-half of the potash taken up by the plant when the active potash exceeds 100 parts per million. When the active potash is between 50-100 parts per million, the loss is about one-fifth of the potash taken up by the plant. When the active potash is about 50 parts per million or less, there may be no observed loss.