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DIVISION OF CHEMISTRY

THE RELATION OF THE PHOSPHORIC ACID OF THE SOIL TO POT EXPERIMENTS

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BULLETIN No. 267. OCTOBER, 1920.

THE RELATION OF THE PHOSPHORIC ACID OF THE SOIL TO POT EXPERIMENTS.

BY G. S. FRAPS.

One of the most important problems of agricultural chemistry is to determine the relation between the chemical analysis of the soil and the need of the soil for plant food. The problem is a complex one, as a number of factors enter into the matter. In previous bulletins, it has been shown that there is a relation between the active phosphoric acid of the soil and the results in pot experiments. This bulletin carries the subject further and deals with the relation between the phosphoric acid, the chemical composition, and the results of pot experiments. Other bulletins have considered the phosphoric acid, the potash, and the humus of the soil.

PREVIOUS WORK.

Bulletin 126 (1909) contained a study of the active phosphoric acid of soils, and showed that the quantity of phosphoric acid extracted from a soil by crops grown in the pot experiments, on an average, increased regularly with the amount of active phosphoric acid extracted from the soil by N/5 nitric acid. It was pointed out that the soil may provide sufficient phosphoric acid for large field crops, and yet respond to fertilization with phosphoric acid in pot experiments, for the reason that conditions in the pot may favor a larger growth of the plant than conditions in the field. It was stated in Bulletin 126 that the plant food withdrawn from the soil by the plant depends upon the form of combination of the plant food, its protection or non-protection by incrusting particles, the action of weathering agencies upon it, and the nature of the plant. The composition of the soil extract depends upon the quantity of the phosphate exposed to the solvent, the solubility of the phosphate under the conditions of the extraction, the solubility of any material which may protect phosphate from the action of the solvent, and the fixing power of the soil for phosphoric acid from the solvent.

Fifth-normal nitric acid dissolved phosphate of lime completely, but dissolved only to a slight extent the iron and aluminum phosphates which usually occur in the soil. It apparently distinguishes between these two classes of compounds. But N/5 nitric acid may not distinguish between different phosphates which have unequal values to plants. Soils absorb phosphoric acid in solution from N/5 nitric acid, and other solvents, so that the amount of phosphoric acid in the extract does not necessarily represent the total amount present and soluble in the solvent. This fact complicates the problem decidedly, since the fixing power of the soil for phosphoric acid must enter into consid-

eration. A portion of the phosphoric acid dissolved by N/5 nitric acid comes from the highly insoluble iron and aluminum phosphates.

Limestone soils may contain phosphates which are protected by the carbonate of lime from the roots of plants, but which are exposed to solution when the carbonate of lime is dissolved by the solvent.

It is difficult to allow for the effects of phosphates protected by incrusting material, and for fixation by the soil, in considering the relation of the active phosphoric acid of the soil to pot experiments, and needs of the soil in the field. A soil with a high fixing power may really contain large amounts of active phosphoric acid but the extract may contain only a small amount.

In Bulletin 178 (1915) it was shown that the presence of carbonate of lime may increase the quantity of phosphoric acid taken up from phosphates of the soil in pot experiments. The presence of carbonate of lime, or of vegetable matter, may bring about differences in the quantity of phosphoric acid assimilated by plants from soils containing equal quantities of active phosphoric acid. The addition of carbonate of lime caused an increase in the quantity of the phosphoric acid taken up equal to three to seven bushels per acre per crop of corn, while the vegetable matter in three cases caused a gain in phosphoric acid taken up equal to two or three bushels of corn per acre.

Bulletin 212 (1917) deals with the availability to corn and sorghum of the phosphoric acid of rock phosphate, which is chiefly in the form of phosphate of lime. There were very decided variations in the value of rock phosphate in different soils. The average recovery of phosphoric acid from rock phosphate in 21 experiments was 9.1 ± 1.1 per cent. This work is of significance in connection with the fact that the active phosphoric acid of the soil is believed to come chiefly from phosphates of lime. The first crop removes 5.3 per cent., on an average, of the phosphoric acid from rock phosphate. The phosphoric acid of rock phosphate thus has a low availability to corn and sorghum. The influence of large quantities of rock phosphate upon the amount of phosphoric acid taken from the soil is being studied.

Bulletin 126, referred to above, showed that the active phosphoric acid of the soil is, on an average, related to the deficiency of the soil for phosphoric acid in pot experiments, but there were deviations from the average, and the object of the present bulletin is to ascertain, if possible, the causes of the deviation.

METHOD OF WORK.

The object of the present work is to ascertain the relation between the phosphoric acid in the soil and the results of pot experiments. For the purpose of this work, the samples of the soil were divided in series according to the contents of active phosphoric acid. Two portions of 5000 grams each of the soil were weighed out in galvanized-iron pots, and one portion received a complete fertilizer, consisting of dicalcium phosphate, ammonium nitrate, and sulphate of potash. The other pot received only nitrogen and potash. The amount of soil on hand in most cases did not permit the planting of duplicate pots. Two crops were grown each year, the first crop being corn and the second crop being sorghum. As a rule, four crops were grown for the purpose of the experiment, although a larger number of crops was grown in some cases. The pots were kept in a green house, or in plant houses consisting of

small frame houses with glass tops, and canvas tops and sides. After harvest, the crops were dried, weighed, and subjected to analysis.

Each series of soils was kept under the same conditions as far as possible, and treated alike. As stated above, the soils of each series contain the same quantity of active phosphoric acid.

Detailed results of the experiments are given in Table 28.

RELATION OF CROPS TO ACTIVE PHOSPHORIC ACID.

Table 1 shows the average relations of the active phosphoric acid to the average results of the pot experiments. The total weight of the four crops, grown in the KN pots which did not receive phosphoric acid, increases with the active phosphoric acid content of the soil, with the

Table 1.—Average results of four crops on the soils.

	Active phosphoric acid per million	K P N Four crops, grams	K N Four crops total grams	K N per crop grams	Phosphoric acid four crops grams	Phosphoric acid per crop, grams	Phosphoric acid per million per crop	Corn possibility of phosphoric acid per crop	Number of soils
Series 131, 29	7.3	113.1	28.0	7.0	.0546	.0136	2.7	8.6	18
Series 4, 14, 30, 47	14.8	104.7	41.2	10.3	.0903	.0226	4.5	14.4	44
Series 36	25.1	120.4	55.9	14.0	.1117	.0279	5.6	18.0	9
Series 28	34.8	138.3	103.8	25.9	.2562	.0640	12.8	41.0	8
Series 17 and 27	48.3	115.4	78.0	19.5	.1635	.0409	8.2	26.2	16

exception of series 28. The average weight per crop increases in a similar way. The same is observed with respect to the grams of phosphoric acid removed by the crop, and also in parts per million of soil. The corn possibility of the phosphoric acid is based on the assumption that 40 bushels of corn require 25 pounds of phosphoric acid, and that it is removed from the surface 7 inches of the soil, which weighs two million pounds per acre. The corn possibility varies from 8.6 bushels with soils containing 0 to 10 parts per million of active phosphoric acid, to 26.6 bushels for soils containing 40 to 60 parts per million.

Table 2.—Average corn possibility of different tests in bushels per acre.

Group	1	2	3	4	5	6	7	8	9
Phosphoric acid content of soil	0–10	10.1–20	21–30	31.1–40	40.1–60	60.1–80	80.1–100	100.1–190	320–420
Average corn possibility, Bulletin 126	4.5	12.5	20.8	19.7	24.4	26.5	22.0	52.5	60.7
Maximum corn possibility, Bulletin 126	9	31	36	37	42	59	39	101	94
Standard of interpretation, Bulletin 161	6	12	18	24	30	35	40	45	.....
Average four crops, Series 4–47	8.6	14.4	18.0	41.0	26.2	.....	.....	.....	.....
Average three crops, Series 4–47	10.2	15.2	20.2	44.8	27.2	.....	.....	.....	.....

These average results are compared in Table 2 with the figures from Bulletin 126, and also the revised table based upon later work and published in Bulletin 161.

The experiments described in Bulletin 126 include some in which the plant suffered from adverse conditions. The results of this series of experiments are therefore somewhat lower than the results of the later experiments. The relation between the other two series of experiments is remarkably close, considering the nature of the work.

RELATIONS OF SUCCESSIVE CROPS.

Table 3 contains the average results of the first crop, which was corn. Table 4 contains the average results of the first and second crops combined. Table 5 contains the average results of the first, second, and third crops combined. Table 6 contains the fourth crop by itself. The average weights of the first and second crops combined per crop are slightly less than the average of the first crop. The average weights of the first, second, and third crops are slightly less than the average of the first and second crops. There is a decided falling off in weight of the fourth crop, as it is only about one-half the weight of the first crop. It is a question whether, or not, the growth of two crops alone would not give as good results as the growth of four crops. There is such a large falling off with the fourth crop that it would be probably better to discontinue growing it, except for special work. The third crop (corn) is usually a good one but it would appear from the results here given that except for special work the first two crops might be sufficient. However, the results of the four crops are not always the same as the results of the first two crops.

Table 3.—Average results of the first crop (corn).

	Active Phosphoric Acid per Million	Crop KN gm.	Crop KPN gm.	Phosphoric Acid gm. per pot	Phosphoric Acid per Million of soil
Series 13 and 29	7.3	8.2	27.3	.0193	3.9
Series 4, 14, 30, 47	14.8	13.8	34.9	.0298	6.0
Series 36	25.1	19.0	34.3	.0493	9.9
Series 28	34.8	31.0	37.0	.0878	17.6
Series 17 and 27	48.3	25.7	35.7	.0623	12.5

Table 4.—Average results of the first and second crops.

	Active Phosphoric Acid per Million	KPN Total gm.	KN Total gm.	KN per crop gm.	Phosphoric Acid per crop gm.	Phosphoric Acid per Million
Series 13 and 29	7.3	43.6	16.9	8.5	.0178	3.5
Series 4, 14, 30, 47	14.8	62.4	28.8	14.4	.0323	6.4
Series 36	25.1	56.1	33.1	16.6	.0384	7.7
Series 28	34.0	67.2	57.2	28.6	.0801	16.0
Series 17 and 24	48.3	50.0	45.4	22.7	.0539	10.8

Table 5.—Average results of three crops.

	Active Phosphoric Acid per Million	KPN Total gm.	KN Total per crop gm.	KN per average crop gm.	Phosphoric Acid per crop gm.	Phosphoric Acid per Million
Series 13 and 29.....	7.3	84.7	25.2	8.4	.0159	3.2
Series 4, 14, 30, 47....	14.8	96.0	38.7	12.9	.0283	3.7
Series 36.....	25.1	87.0	43.4	14.5	.0315	6.3
Series 28.....	34.8	118.2	83.0	27.7	.0696	14.0
Series 17 and 27.....	48.3	88.3	67.9	22.6	.0474	8.5

Table 6.—Results of the fourth crop.

	Active Phosphoric Acid per Million	KPN crop gm.	KN crop gm.	Phosphoric Acid gm.	Phosphoric Acid per Million
Series 13 and 29.....	7.3	17.0	3.5	.0079	1.6
Series 4, 14, 30, 47.....	14.8	20.2	8.0	.0168	3.3
Series 36.....	25.1	32.9	12.5	.0172	3.4
Series 28.....	34.8	29.5	20.6	.0475	9.5
Series 17 and 27.....	48.3	17.1	10.6	.0220	4.4

The conclusion is the same whether we consider the first crop alone, the first and second crops combined, the first three crops combined, or the fourth crop alone, or all four crops combined, or whether we consider the size of the crop or its phosphoric acid contents. This conclusion is that on an average the size of the crop, or the amount of phosphoric acid taken up, is related to the active phosphoric acid of the soil.

Series 28 does not fit in well with the others, but produces a larger crop in proportion to the quantity of active phosphoric acid in the soils. There are eight soils in this series. The active phosphoric acid in these soils appears to average unusually high in crop-producing capacity.

Table No. 7 contains the average results by series. Series No. 27 and series No. 28 are not so well in line with the other results. Series 27 is too low, while series 28 is too high.

Table 7.—Average results by series.

Series number	13	29	4	14	30	47	36	28	17	27
Active phosphoric acid	7.20	18.20	14.90	16.10	15.80	14.80	25.10	33.20	54.70	46.60
Crop No. 1—Grams corn KN	7.36	9.39	8.87	17.36	15.38	11.92	18.97	31.01	31.75	22.12
Crop No. 2—Sorghum KN	7.71	9.99	11.17	11.86	11.25	8.23	14.14	26.21	18.98	20.18
Crop No. 3—Corn KN	9.39	6.60	12.60	11.01	10.59	5.03	10.30	26.00	29.60	18.30
Crop No. 4—Sorghum KN	4.23	2.54	4.58	13.13	9.01	4.60	12.52	20.55	11.667	9.91
Total	28.69	28.52	37.22	43.36	46.23	29.78	55.93	103.77	92.00	70.51
Crop No. 1—Corn Grams KPN	25.71	33.47	48.27	35.85	29.38	34.11	34.30	37.01	43.81	30.92
Crop No. 2—Sorghum KPN	19.46	30.30	21.26	19.91	18.73	21.74	21.83	30.16	20.37	28.21
Crop No. 3—Corn KPN	44.85	35.26	39.67	37.45	33.17	25.40	31.03	41.61	44.82	34.37
Crop No. 4—Sorghum KPN	24.71	16.50	15.88	30.12	15.68	16.20	32.88	29.52	16.12	17.82
Total	114.73	115.53	125.08	123.37	96.96	97.45	120.04	138.30	125.11	111.32
Per cent phosphoric acid—Crop No. 1	.281	.187	.230	.210	.251	.211	.270	.275	.213	.298
Per cent phosphoric acid—Crop No. 2	.173	.207	.190	.230	.280	.223	.171	.270	.230	.250
Per cent phosphoric acid—Crop No. 3	.148	.171	.210	.210	.205	.250	.199	.181	.125	.192
Per cent phosphoric acid—Crop No. 4	.196	.204	.190	.250	.199	.195	.136	.209	.20	.208
Grams phosphoric acid—Crop No. 1	.0204	.0174	.0208	.0333	.0358	.0229	.0493	.0878	.0678	.0589
Grams phospnoric acid—Crop No. 2	.0131	.0205	.0198	.0275	.0276	.0216	.0276	.0725	.0410	.0465
Grams phosphoric acid—Crop No. 3	.0135	.0116	.0253	.0219	.0213	.0122	.0176	.0484	.0368	.0345
Grams phosphoric acid—Crop No. 4	.0083	.0044	.0088	.0319	.0174	.0084	.0172	.0475	.0224	.0217
Total	.0553	.0539	.0747	.1146	.1021	.0651	.1117	.2562	.1680	.1616

It has already been pointed out in this and previous bulletins that some soils are unusually high in their crop-producing power for the amount of active phosphoric acid present and some are unsually low; that organic matter and lime affect the amount of phosphoric acid withdrawn; that the phosphoric acid of rock phosphate is unequally taken up from different soils. It is the object of the present bulletin to ascertain the cause of these variations, if possible.

WHAT SHALL REPRESENT THE FERTILITY.

The question as to which results best express the fertility of the soil with respect to phosphoric acid, is open to discussion and differences of opinion. Should the weights of the crops be used, or the relative weight of the crop with complete fertilizer to that without phosphoric acid? Should the first crop, or the first plus the second, or four crops be used; should the phosphoric acid removed be used instead of the weight of the crops? These are the questions which arise. When the different methods give the same results, as occurs with a number of the soils, there is no question, but when the different methods give rise to different results, the case is different.

GROUPS OF HIGH, LOW, AND MEDIUM PRODUCTION.

In order to study the relation between the chemical composition and other properties of the soil, it was decided to arrange the soils in three groups within each series as follows: The first group consists of those 25 per cent. or more below the average of the group. The second group consists of those within 25 per cent. of the average of the group. The third group consists of those 25 per cent. or more above the average of the group. The series are arranged according to the amount of active phosphoric acid.

Since there is some variation in the yields of the crops from the different tests on the same soil, and the amount of phosphoric acid withdrawn by the crops, there would be some difference in the grouping of the soils according to the method adopted in arranging them. In order to study this, the soils were arranged in three groups above mentioned, according to the following several ways: (a) The weight of the first crop; (b) the weight of the second crop added to the weight of the first crop; (c) the weight of phosphoric acid taken up by the first crop; (d) the weight of phosphoric acid taken up by the second crop added to that taken up by the first crop; (e) the total weight of the four crops; (f) the total weight of the phosphoric acid taken up by the four crops.

In most cases the grouping is the same no matter which of the above methods was used. For the purposes of this work, the soils were finally arranged according to the total quantity of phosphoric acid taken up by the crops, with the exception of two soils. Soils No. 968 and 5969 were placed in the first group for the reason that all of the results excepting the total phosphoric acid placed them in this group.

Table 8.—Groups based on average phosphoric acid removed by crops.

Series	13	29	4	14	30	47	36	28	17	27
Group 1—Below average 25 per cent or more	335	7242	2343	3400	7234	9314	9187	5954	4291	6882
	6681	7245	1135	4187	7154	9285	.....	7241	.....	7252
	3378	7255	968	5967	7150	9164	.....	6976	.....	A2C3D3
		A2C2D3	F2	.....	.....	.....	.....	A2B2C2		
	4234	.....	.....	6884	4650	.....	.....	.....	.....	.....
				A2B2						
	4596	.....	.....	.....	1200	.....	.....	.....	.....	.....
	B2D3	.....	.....	.....	C2					
	3362	.....	.....	.....	.....	.....	.....	.....	.....	.....
	A2B2									
Group 2—Within average	2350	7121	992	6680	7224	9168	9311	5966	5945	7169
			A1							
	3611	7238	.....	.....	7162	9353	.....	7227	2353	970
	E1C3					E3			A1	A1B1
	.....	7120	937	.....	7181	9279	9305	5958	936	C1D1
		B3C3	A3B3			A3B3			B1	7240
		D3	C3		7266	C3	7346			A1B1
			913		A1B1	9277	E1			D1E1
			A3B3		D1E1	A3B3	9333			7159
			C3D3		5956	D3	E1			A2B3
					A1C1		9378			7265
					7233		C3			A3B3
					E1					6883
					7228					B3
					B3C3					
					D3					
					7237					
					7244					
					E2					
					7254					
					A3D1					
Group 3—Above average 25 per cent or more	5544	7251	1137	4186	7118	9183	7341	5953	5100	7225
				A3B2		A2B2				
				C2		C2D2				
	5710		2944	3333	7145	E2	7708	5957	5943	7107
							A2B2		B2	A2B2
							C2D2			
	5969			894	2828	9331				
	F2				A2C2	B2E2				

Table 8 shows the soils arranged according to the phosphoric acid removed by four crops, and it also shows the differences that would occur if the other arrangements were used. When a letter and figure is given below the soil number, it shows that if arranged according to method A, B, C, D, E, or F, as the case might be, the soil would be changed to group 1, 2, or 3, as noted. For example, soil 992 (series 4, group 2), would be placed in group 1 if the weight of the first crop alone were considered. Soil 937 (series 4, group 2) would be placed in the third group if the weight of the first crop (A), the weights of the first and second crops (B), and the phosphoric acid in the first crop (C), were considered.

It is interesting to consider what changes would occur if the total phosphoric acid taken up by the first and second crops were considered, instead of the phosphoric acid taken up by the four crops. This would involve the following changes. In series 4 soil 913 would be moved from group 2 to group 3. In series 13, 14, 17, 28 there would be no change. In series 27 soil 7252 would be moved from group 1 to group 3, and soils 970 and 7240 would be moved from group 2 to group 1. In series 29 soil 7255 would be moved from group 1 to group 3. In series 30 soil 7266 would be moved from group 2 to group 1, and soil 7228 from group 2 to group 3. In series 36 soil 7708 would be moved from group 3 to group 2. In series 47 soil 9277 would be moved from 2 to group 3, and soil 9183 would be moved from group 3 to group 2. There would be change in the grouping of 10 out of the 95 soils or about 10 per cent. This cannot be considered a large percentage.

We can also consider what changes would be caused if the arrangement were based on the weight of the first two crops. In series 4 soils 937 and 913 would be changed from the second group to the third group. In series 13 soils 4596 and 3362 would be moved from the first group to the second group. In series 14 soil 6884 would be moved from first group to the second group. In series 17 soil 5943 would be moved from the third group to the second group. In series 27 soils 970 and 7240 would be moved from the second to the first group, and soils 7159, 7265 and 6883 from the second group to the third group. Soil 7107 would be moved from the third group to the second group. In series 28 soil 6976 would be moved from the first group to the second. In series 29 soil 7120 would be moved from the second group to the third group. In series 30 soil 7666 would be moved from the second group to the first group, and soil 7228 from the second group to the third group. In series 36 soil 7708 would be moved from the second group to the third group. In series 47 soil 9279 would be moved from the second group to the third group, and soils 9183 and 9331 would be moved from the third group to the second group. There would be movement in the position of twenty-one soils, or about 22 per cent. of the soils under study. The consideration of the weight of first and second crop would, therefore, involve about twice as many changes as the consideration of the phosphoric acid removed by these crops. The phosphoric acid taken up seems to be a less variable condition than the weight of the crop, even though there is added the analytical error involved in the determination.

It is evident from the above discussion that the grouping based upon the first two crops would be different in a number of cases from those based upon four crops. Sometimes the soils produce better the

first year than they do the second, and less often the crops are poor the first year and much better the second year. As already pointed out, and as shown in Table 1, the results of series 28 are out of line with the others.

Another method of arranging the results is with respect to the calculated average phosphoric acid that should be withdrawn by the crops based upon the active phosphoric acid present, rather than on the actual average of each series. This method requires that all of the crops should be grown under the same conditions, which is not exactly the case, since even when the crops are grown at the same time, they are not under exactly the same conditions. See Table 9.

Table 9.—Method of arranging according to calculated phosphoric acid.

Group	1	2	3	4	5
Active phosphoric acid	0–10	10–20	20–30	30–40	40–60
Assumed corn possibility, bushels	10	15	20	25	30
Parts per million phosphoric acid from soil	3.1	4.7	6.2	7.8	9.4
Grams per pot of 5000 gm., average	.0155	.0235	.0310	.0390	.0470
25 per cent below, per crop	.0116	.0176	.0233	.0292	.0357
25 per cent above, per crop	.0194	.0294	.0387	.0498	.0587

Table 10 shows the arrangement in groups based on the calculated phosphoric acid removed by the four crops. The small figure with some of the other figures shows the variations from the grouping based upon the average phosphoric acid of the series. Thus in series 13 soil 3611 would appear in group 2 if the grouping were in accordance with the average, instead of appearing in group 1. Soil 5969 would appear in group 3.

Table 10.—Groups based on calculated phosphoric acid removed by four crops.

Series	13	29	4	14	30	47	36	28	17	27
Below average 25 per cent or more	335	7225	968	3400	7234	9314	9187	.....	4291	970[2]
	6681	7255	2343	4187	7154	9164	.....	.....	2353[2]	7240[2]
	3378	.....	1135	6884	4650	9285	.....	.....	.....	6882
	4234	.....	937[2]	.....	7150	9168[2]	.....	.....	.....	7252
	4596	.....	.....	.....	1200	9353[2]	.....	.....	.....	.....
	3362	.....	.....	.....	.....	9279[2]	.....	.....	.....	.....
	3611[2]	.....	.....	.....	.....	.....	.....	.....	.....	.....
Within 25 per cent of average	.....	.....	992	5967	.....	9183[3]	7346	5954[1]	936	7169
	.....	.....	1137[3]	6680	.....	9331[3]	7708[3]	7241[1]	5945	6883
	.....	.....	913	.....	.....	9277	9333	6976[1]	5100[3]	7159
	2350	7121	.....	.....	7266	.....	9311	.....	.....	7265
	5969[3]	7238	.....	.....	5956	.....	7374	.....	.....	.....
	.....	7242[1]	.....	.....	7224	.....	9305	.....	.....	.....
	.....	7120	.....	.....	7162	.....	9378	.....	.....	.....
	.....	7251[3]	.....	.....	7181	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7233	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7233	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7254	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7237	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7244	.....	.....	.....	.....	.....
Above average 25 per cent or more	.....	.....	2944	4186	.....	.....	7341	5958[2]	5943	7107
	.....	.....	.....	.....	.....	.....	.....	5966[2]	.....	7225
	5944	.....	.....	3333	.....	.....	.....	7227[2]	.....	.....
	5710	.....	.....	894	.....	.....	.....	5953	.....	.....
	.....	.....	.....	.....	.....	.....	.....	5957	.....	.....
	.....	.....	.....	.....	2828	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7228[2]	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7118	.....	.....	.....	.....	.....
	.....	.....	.....	.....	7145	.....	.....	.....	.....	.....

The following differences are found in the table from the arrangement by averages (Table 8). In series 3 there are two changes, two in series 29, two in series 4, one in series 14, one in series 30, five in series 47, one in series 36, six in series 28, two in series 13, and two in series 27. There are thus twenty-four changes, or something over 25 per cent. The greatest number of changes occur in series 47 and 28. In series 47 the positions of the soils are lowered, while in series 28 the positions of the soils are raised. In series 28 three soils are shifted from the first series to the second series by basing the grouping on the calculated phosphoric acid.

METHOD OF CHEMICAL ANALYSIS OF THE SOIL.

The active phosphoric acid and active potash were determined by solution in fifth-normal nitric acid, without correction for the acid neutralized. They are expressed in parts per million. The acid consumed represents the percentage of the acid neutralized in the process of extracting the active phosphoric acid and potash. It represents the bases neutralized by the acid. It is expressed in percentage of the acid used. The nitrogen was determined by the usual method. The phosphoric acid absorbed represents the percentage of phosphoric acid taken from twenty milligrams of phosphoric acid in contact with one hundred grams of soil and 200 cc. of water. The acidity was determined by the Veitch method; lime by the Hilgard method.

Active phosphoric acid extracted by five successive extractions with fifth normal nitric acid was made by washing the residue back into the extraction bottle and making another extraction, until five had been made. The phosphoric acid was determined separately in each extract.

Phosphoric acid soluble in cold 12 per cent. hydrochloric acid was determined before ignition, and after ignition. The difference is termed ignition soluble phosphoric acid, and is considered by some chemists to represent the phosphoric acid in organic combination. This may be the case to some extent, but we have shown elsewhere that ignition will render some mineral phosphates soluble in acid.

RELATION OF CROPS TO THE CHEMICAL COMPOSITION OF SOILS MORE OR LESS PRODUCTIVE THAN THE AVERAGE.

Table 11 gives the average chemical composition of the soils used in these pot experiments, arranged in series according to the content of active phosphoric acid, and these series divided in groups according to the average phosphoric acid removed by the crops, the groups being based on those 25 per cent. or more below the average, 25 per cent. below to 25 per cent. above the average, and 25 per cent. or more above the average as previously described.

Table 11 shows the average composition and the crop production of the soils based on the average for each series. A similar arrangement was made of the soils in the groups arranged by the calculated phosphoric acid removed, and the results of this calculation are given in Table 12.

Table 11.—Average composition and crop production of soils based on average for series.

	Number averaged	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed	Active Potash per million	Wt. of first crop	Wt. of four crops	Phosphoric acid removed by four crops
		Active per million	Active extract per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent							
Series 13–29.															
Below 25 per cent	9	6.4	52	0.030	0.0063	0.0134	0.0071	62.4	0.044	0.21	8.6	122	5.0	17.2	0.0336
Within 25 per cent	5	8.2	77	0.032	0.0079	0.0147	0.0068	62.8	0.059	0.31	4.1	90	8.8	29.5	0.0565
Over 25 per cent	4	8.3	68	0.056	0.0107	0.0179	0.0072	39.5	0.050	0.14	3.4	76	14.5	50.3	0.0958
Series 4, 14, 30, 47.															
Below 25 per cent	15	13.3	95	0.046	0.0155	0.0244	0.0089	45.7	0.055	1.54	.....	118	8.3	22.5	0.0445
Within 25 per cent	18	16.2	116	0.045	0.0181	0.0353	0.0172	43.5	0.0076	2.75	17.0	178	15.3	43.5	0.0915
Over 25 per cent	10	17.7	103	0.062	0.0200	0.0392	0.0192	5.16	0.090	2.78	26.1	153	19.3	62.3	0.1414
Series 36															
Below 25 per cent	1	32.8	128	0.046	0.0104	0.0290	0.0186	.....	0.089	0.65	13.2	144	7.2	29.4	0.0577
Within 25 per cent	5	24.6	95	0.034	0.0108	0.0199	0.0091	.....	0.094	0.28	1.7	97	21.4	52.7	0.1080
Over 25 per cent	2	22.3	76	0.035	0.0091	0.0231	0.0140	.....	0.121	1.03	17.2	124	17.0	73.4	0.1571
Series 28															
Below 25 per cent	3	32.8	266	0.054	0.0143	0.0227	0.0084	42.7	0.102	8.42	36.0	161	20.7	70.7	0.1498
Within 25 per cent	3	34.1	389	0.093	0.0510	0.0720	0.0210	72.8	0.133	4.70	43.1	228	33.7	104.6	0.2261
Over 25 per cent	2	39.0	535	0.136	0.0738	0.1179	0.0441	77.6	0.186	9.61	61.9	427	42.4	152.2	0.4612
Series 17, 27															
Below 25 per cent	3	44.2	174	0.043	0.0235	0.0422	0.0187	47.1	0.051	5.84	47.1	167	16.1	42.2	0.0971
Within 25 per cent	9	48.5	128	0.034	0.0147	0.0263	0.0116	28.3	0.045	0.41	6.0	183	24.1	78.1	0.1535
Over 25 per cent	4	51.3	117	0.039	0.0143	0.002	0.0103	38.2	0.043	0.31	4.4	151	36.8	104.5	0.2360

Table 12.—Average composition based on groups, arranged by calculated phosphoric acid.

	Number averaged	Phosphoric Acid						Nitrogen per cent	Lime per cent	Acid consumed	Active potash per million
		Active per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent				
Series 13–29.											
Below 25 per cent	9	8.2	.031	.0069	.0142	.0073	62.9	.046	.15	8.6	126
Within 25 per cent	7	8.2	.038	.0077	.0145	.0068	56.7	.051	.13	3.7	73
Over 25 per cent	2	8.4	.055	.0117	.0185	.0068	43.1	.059	.17	4.0	110
Series 4, 14, 30, 47.											
Below 25 per cent	18	13.3	.047	.....	.....	.....	28.9	.049	1.09	5.1	122
Within 25 per cent	17	16.3	.053	.0221	.0390	.0169	43.7	.077	3.69	23.7	172
Over 25 per cent	8	18.6	.056	.0218	.0429	.0211	54.7	.104	3.43	32.7	138
Series 36.											
Below 25 per cent	1	32.8	.046	.0104	.0290	.0186	.....	.089	.65	13.2	143
Within 25 per cent	7	30.6	.041	.0156	.0265	.0109	18.2	.104	1.71	16.8	104.7
Over 25 per cent	1	22.2	.038	.0108	.0257	.0149	.....	.105	1.49	25.2	161
Series 28											
Below 25 per cent	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Within 25 per cent	3	32.8	.054	.0144	.0228	.0084	42.8	.102	8.59	35.9	161
Over 25 per cent	5	36.1	.107	.0602	.0903	.0301	74.7	.....	6.66	50.6	308
Series 17–27.											
Below 25 per cent	6	45.2	.037	.0199	.0357	.0158	43.0	.043	3.08	25.6	182.5
Within 25 per cent	7	51.2	.....	.0139	.0250	.0111	21.0	.049	.42	6.3	176
Over 25 per cent	3	48.2	.042	.0141	.0240	.0099	47.7	.048	.33	5.2	141

There are no great differences to be found in the conclusions to be drawn from these two tables. The conclusions are prectically the same whichever one is used.

In some series, the total phosphoric acid is higher in the soils which produce over 25 per cent. more than the average, but in the other series the results are irregular. This relation occurs more often with the soils arranged according to the calculated phosphoric acid, than with those arranged according to the averages of the series.

The acid consumed is irregular, and no average relation can be traced.

In three of the five series the nitrogen averages are higher with the soils that produce more than the average; the other two are irregular. There is some tendency for a higher nitrogen content to accompany higher amounts of phosphoric acid taken from soils containing the same amount of active phosphoric acid. As a rule, the content of nitrogen represents the content of organic matter in the soil. Thus there is apparently some tendency for the soils of the same active phosphoric acid content to give up more phosphoric acid when they contain more organic matter. In Bulletin 178, we gave results in which the addition of organic matter increases the quantity of phosphoric acid taken from the soils. This relation does not always occur in the soils under examination. It can only be noted as a tendency.

The phosphoric acid absorbed is irregular, and no relation can be traced.

The lime is irregular and no relation can be traced.

The active potash is irregular and no relation can be traced.

The phosphoric acid soluble in cold 12 per cent. hydrochloric acid on an average, increases with the first, second, and fourth series but it decreases with the third and fifth series. This relation is parallel with the total phosphoric acid, as might be expected.

The ignition-soluble phosphoric acid is irregular. It increases in the second and fourth series, but decreases or is irregular with the other series.

Apparently the only conclusion that can be drawn from these averages is that there is a tendency for the larger amounts of phosphoric acid to be withdrawn from soils containing the same amount of active phosphoric acid, when these soils contain a higher nitrogen content and a higher total phosphoric acid content. The other relations appear to be irregular.

It is of course probable that the cause of the variation in the amount of phosphoric acid withdrawn from soils of the same active phosphoric acid content varies with the soil, and is due to one thing in one soil and to another in another soil, and these relations may be averaged out. There are also probably other causes outside of our present knowledge.

RELATION OF CROPS TO SURFACE SOIL OR SUBSOIL.

Table 13 shows the average relation of surface soils to subsoils in groups arranged according to their content of active phosphoric acid. by crops. This discussion of course refers entirely to the active phosphoric acid of the soil and the phosphoric acid withdrawn by crops. The first crop, the weight of the four crops, and the weight of phosphoric acid removed by four crops average less for the subsoils than for the surface soils, with the first series, the second series, and the fourth series. With the third series, the average weight of the first

Table 13.—Relation of surface soils to subsoils.

	Surface soil	Subsoil
Series 13–29. Active phosphoric acid, 7.3		
Number of soils	3	15
First crop K N grams	11.4	7.5
Four crops K N grams	32.2	25.9
Phosphoric acid, four crops, grams	.0781	.0489
Four crops with complete fertilizer	127.5	110.3
Series 4, 14, 30, 47. Acid phosphoric acid, 14.8		
Number of soils	24	20
First crop, grams	16.7	11.0
Four crops, grams	48.7	32.1
Phosphoric acid, four crops, grams	.1031	.0724
Four crops with complete fertilizer	114.9	93.9
Series 36. Active phosphoric acid, 25.1		
Number of soils	2	7
First crop	18.8	19.0
Four crops	53.9	56.5
Phosphoric acid, four crops	.1094	.1171
Four crops with complete fertilizer	114.2	121.7
Series 28. Active phosphoric acid, 34.8		
Number of soils	6	2
First crop	34.5	20.5
Four crops	109.7	85.9
Phosphoric acid, four crops	.2700	.1821
Four crops with complete fertilizer	141.5	128.7
Series 17, 27. Active phosphoric acid, 48.3		
Number of soils	11	5
First crop	30.1	16.2
Four crops	78.7	76.3
Phosphoric acid, four crops	.1649	.1605
Four crops with complete fertilizer	112.8	121.2
Average by groups:		
First crop, grams	22.8	14.8
Four crops, grams	68.1	55.3
Phosphoric acid, four crops	.1495	.1162

crop produced by the subsoils is equal to that produced by the surface soils, as are also the weights of the four crops and the phosphoric acid removed by the four crops. With the fifth series, the average weight of the first crop with the subsoils is much less than the weight of the first crop on surface soils, but the phosphoric acid removed and the total weight of the four crops, are practically the same. In three of the series the weight of the four crops with a complete fertilizer are lower with the subsoils than the surface soils, while with the other two series the reverse is the case.

On an average of all the groups, the surface soil produces first crops about 50 per cent. larger than the subsoil. The surface soil produces about 25 per cent. larger crops when the four crops are considered, than the subsoil. The average amount of phosphoric acid removed is about 25 per cent. greater for the four crops for the surface soil than for the subsoil.

We may conclude that surface soils containing the same amount of active phosphoric acid, will, on an average, give up more phosphoric acid to crops than subsoils containing corresponding amounts of active phosphoric acid. It is hardly necessary to point out that this average relation does not hold in all cases, and that some subsoils give up more phosphoric acid than surface soils of the corresponding phosphoric acid content. This is also shown in Table 14.

Table 14.—Relation of surface soil to subsoil from Bulletin 126.

Active Phosphoric Acid per Million		Surface soil	subsoil
0–10	Number of soils	11	1
	Average crop, KPN, grams	15.9	20.2
	Average crop, KN, grams	3.0	4.0
10–20	Number of soils	11	8
	Average crop, KPN, grams	17.4	24.2
	Average crop, KN, grams	5.4	4.6
20–30	Number of soils	6	10
	Average crop, KPN, grams	15.8	27.6
	Average crop, KN, grams	8.0	2.5
30–40	Number of soils	4	0
	Average crop, KPN, grams	10.1	.....
	Average crop, KN, grams	7.1	.....
40–60	Number of soils	8	0
	Average crop, KPN, grams	11.1	.....
	Average crop, KN, grams	8.7	.....
60–80	Number of soils	4	10
	Average crop, KPN, grams	20.7	23.0
	Average crop, KN, grams	19.0	12.9
80–100	Number of soils	6	1
	Average crop, KPN	11.6	2.0
	Average crop, KN, grams	13.9	24.3
100–150	Number of soils	3	1
	Average crop, KPN, grams	13.2	29.7
	Average crop, KN, grams	15.5	6.0
Over 150	Number of soils	9	.....
	Average crop, KPN, grams	26.6	.....
	Average crop, KN, grams	21.6	.....

RELATION OF TOTAL PHOSPHORIC ACID.

The soils arranged in series based on the amount of active phosphoric acid present, are also arranged in sub-groups according to their total phosphoric acid content: those containing less than 0.02 per cent., those containing .021 to .04 per cent., those containing .041 to .06 per cent., and those containing over .06 per cent. phosphoric acid. The average results of this arrangement are given in Table 15.

The average results in the different series are irregular. In some series there is a tendency to an increased withdrawal of phosphoric acid as the amount of total phosphoric acid increases. In other series this is not evident. There is not a sufficient number of soils in the sub-group of some series to form a proper average.

The average by groups is also given in the table. The average weight of the first crops increases as the total phosphoric acid increases with the first three groups, but decreases with the fourth. The average weight of the four crops grown, increases as the total phosphoric acid increases with the first three groups, but decreases with the fourth slightly. The amount of phosphoric acid removed increases with the first three groups but decreases with the fourth. There is thus some tendency for the soils containing the same active phosphoric acid to give up more phosphoric acid to crops as the total phosphoric acid increases, but this difference is not clearly marked.

THE RELATION OF THE NITROGEN CONTENT.

Table 16 shows the relation of the nitrogen content of the soil to the crop production of the phosphoric acid of soils arranged according to the active phosphoric acid and divided into sub-groups according to nitrogen content.

Table 15.—Relation of total phosphoric acid to crop production in groups by active phosphoric acid.

Total phosphoric acid	0–.02	021–.04	.041–.06	Over .06
Series 13–29. Active phosphoric acid, 7.3				
Number of soils	3	9	3	3
First crop	8.0	6.4	14.2	7.5
Four crops	24.5	22.5	48.2	27.2
Phosphoric acid four crops	.0450	.0448	.0960	.0508
Series 4, 14, 30, 47. Active phosphoric acid, 14.8				
Number of soils	8	16	7	12
First crop	14.1	13.2	17.7	11.2
Four crops	32.8	40.6	40.8	45.6
Phosphoric acid four crops	.0650	.0925	.0982	.1034
Series 36. Active phosphoric acid, 25.1				
Number of soils	0	7	1	0
First crop	.....	20.1	7.2	.....
Four crops	.....	58.6	29.4	.....
Phosphoric acid four crops	.....	.1220	.0577	.....
Series 28. Active phosphoric acid, 34,8				
Number of soils	0	2	3	3
First crop	.....	32.4	31.8	29.3
Four crops	.....	81.9	108.2	147.3
Phosphoric acid four crops	.....	.1693	.2511	.3194
Series 17, 27. Active phosphoric acid 48.3				
Number of soils	1	12	2	1
First crop	38.5	24.2	39.7	13.0
Four crops	78.0	78.7	94.0	37.4
Phosphoric acid four crops	.1491	.1669	.1949	.0742
Average by groups:				
Number of soils	12	46	16	19
First crops grown, grams	14.6	16.6	21.2	13.6
Four crops grown, grams	34.4	51.5	60.8	58.3
Phosphoric acid four crops	.0670	.1104	.1360	.1280
Phosphoric acid in soils	.017	.030	.050	.098

Table 16.—Relation of nitrogen content to production in groups according to active phosphoric acid.

Nitrogen	0–.02	.021–.04	.041–.06	Over .06
Series 13–29. Active phosphoric acid, 7.3				
Number of soils	1	4	10	3
First crops, grams	8.4	7.7	6.9	12.9
Four crops	29.6	24.6	24.0	44.9
Phosphoric acid four crops	.0514	.0454	.0469	.0880
Series 4, 14, 30, 47. Active phosphoric acid, 14.8				
Number of soils	0	14	6	22
First crops, grams	.....	13.1	16.3	12.6
Four crops	.....	34.5	38.2	45.3
Phosphoric acid four crops	.....	.0708	.0836	.0992
Series 36. Active phosphoric acid, 25.1				
Number of soils	0	2	1	5
First crops, grams	.....	20.3	22.7	17.0
Four crops	.....	50.5	54.0	56.9
Phosphoric acid four crops	.....	.1013	.1062	.1206
Series 28. Active phosphoric acid, 34.8				
Number of soils	0	0	0	8
First crops, grams	.....	.....	.....	31.0
Four crops	.....	.....	.....	103.8
Phosphoric acid four crops	.....	.....	.....	.2564
Series 17, 27. Active phosphoric acid, 48.3				
Number of soils	0	8	5	3
First crops, grams	.....	26.3	23.2	20.1
Four crops	.....	69.4	76.1	74.5
Phosphoric acid four crops	.....	.1583	.1584	.1683

These soils received nitrogen and potash, but did not receive phosphoric acid. There is shown a tendency to an increased crop and an increased quantity of phosphoric acid given up by the soils, with higher quantities of nitrogen. The differences are not regular, and are not sharply marked. They are better shown with the average phosphoric acid removed by the four crops, and with the average weight of the four crops, than with the first crop. There seems to be a slight tendency for soils which contain an equal amount of active phosphoric acid, to give up more phosphoric acid if they contain more nitrogen, which usually means that they contain more organic matter.

RELATION OF ACIDITY OF THE SOIL.

Table 17 shows the acid and non-acid soils in groups arranged according to the active phosphoric acid. With two of the series, the number of acid soils was so small that no averages were made. The soils which are not acid, on an average, give up more phosphoric acid, and produce larger crops, than those which are acid, with the same

Table 17.—Acid and non-acid soils arranged according to active phosphoric acid.

	Acid	Non-acid
Series 13–39. Active phosphoric acid 7.3		
Number of soils	7	10
First crops grown K N	5.4	9.9
Four crops K N	19.1	33.8
Phosphoric acid four crops	.0357	.0658
Series 4, 14, 30, 47. Active phosphoric acid, 14.8		
Number of soils	9	30
First crops grown	15.5	13.5
Four crops	38.3	41.0
Phosphoric acid four crops	.0775	.0942
Series 36. Active phosphoric acid, 25.1		
Number of soils	3	5
First crops	19.3	18.1
Four crops	48.5	58.8
Phosphoric acid four crops	.1045	.1197
Series 28. Active phosphoric acid, 34.8		
Number of soils	.....	8
Series 17, 27. Active phosphoric acid, 48.3		
Number of soils	1	13

active phosphoric acid content. The difference is large with the first series, small with the second series, and still smaller with the third series. The non-acid soils average nearly twice as large a crop, in the first series, as the acid soils. The differences are much less with the other two groups. The greater the quantity of active phosphoric acid, the less is the average difference between acid and non-acid soils. These relations may not hold for individual soils.

RELATION OF BASES TO PRODUCTION.

Table 18 shows the soils arranged according to the acid consumed. The acid consumed is the percentage of N/5 nitric acid neutralized in the treatment for the estimation of active phosphoric acid and potash, and represents the dissolved lime and magnesia. One hundred per

cent. acid consumed would be equivalent to 10 per cent. carbonate of lime in the soil.

The results are irregular, and no relation can be traced.

Table 18.—Relation of acid consumed to production in groups according to active phosphoric acid.

Acid consumed	0–10	10.1–70	70.1–100
Series 13–29. Active phosphoric acid, 7.3			
Number of soils	16	2	0
First crops grown	8.8	2.8	.....
Four crops	29.0	14.7	.....
Phosphoric acid four crops	.0567	.0302	.....
Series 4, 14, 30, 47. Active phosphoric acid, 14.8			
Number of soils	28	10	5
First crops grown	13.7	10.7	17.3
Four crops	37.7	44.4	52.0
Phosphoric acid four crops	.0839	.0982	.1639
Series 36. Active phosphoric acid, 25.1			
Number of soils	6	2	0
First crops	20.4	12.8	.....
Four crops	56.5	50.3	.....
Phosphoric acid four crops	.1157	.1088	.....
Series 28. Active Phosphoric acid, 34.8			
Number of soils	3	2	3
First crops	29.8	35.3	29.3
Four crops	79.5	125.0	113.9
Phosphoric acid four crops	.1655	.2977	.3194
Series 17, 27. Active phosphoric acid, 48.3			
Number of soils	12	3	1
First crops	28.4	23.5	3.0
Four crops	82.2	74.5	37.4
Phosphoric acid four crops	.1696	.1686	.0742

RELATION OF THE COMPOSITION OF THE SOIL TO THE PHOSPHORIC ACID TAKEN UP BY THE CROPS.

In the preceding discussion, the soils were arranged according to the active phosphoric acid contained in them. It was next decided to reverse this method and to arrange the crops according to the phosphoric acid removed by them from the 5000 grams soils in four crops and examine the relation of the composition and the crop production estimated in this way. The soils were accordingly arranged in following groups:

Group No. 1, phosphoric acid taken up by the four crops, less than .0370 grams or 1.8 parts per million per crop.

Group No. 2, .0371 to .0740 grams or 3.7 parts per million per crop.

Group No. 3, from .0741 to .1054 grams or 5.4 parts per million per crop.

Table 19.—Relation of crops to analyses. Group I.—Below .0370—parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
2343	.0311	11.5	55	.022	.0110	.0197	.0087	83.1	.091	.47	3.0	0	301	9–20	4	4.2	16.7	106.5
335	.0328	6.1	40	.028	.0072	.0139	.0062	90.0	.060	.60	15.2	0	115	Sub.	13	2.1	15.9	76.4
6681	.0206	7.5	53	.024	.0063	.0113	.0050	66.5	.053	.....	4.0	800	59	7–19	13	2.2	11.8	127.3
3378	.0304	6.4	44	.022	.0060	.0083	.0023	85.6	.055	.....	1.0	200	273	6–18	13	2.9	16.2	118.1
4234	.0276	5.1	44	.028	.0040	.0197	.0157	78.5	.043	.....	47.5	500	72	8–16	13	3.5	13.5	76.5
4596	.0362	3.8	67	.063	.0142	.0187	.0045	86.6	.035	.07	3.5	300	228	10–22	13	5.0	17.9	84.2
3362	.0322	6.0	40	.032	.0054	.0147	.0093	89.2	.030	.15	2.1	0	138	8–20	13	5.6	17.1	127.7
7245	.0365	7.5	51	.014	.0033	.0095	.0062	22.5	.042	.07	1.5	230	48	14–20	29	5.2	17.7	102.3
7234	.0369	15.6	74	.054	.0083	.0128	.0045	8.6	.044	.14	0.5	200	66	6–14	30	5.7	13.5	71.8
9164	.0209	13.8	42	.015	.0064	.0100	.0036	51.5	.034	.02	0.5	700	41	9–14	47	4.4	7.0	70.1
9285	.0318	13.4	.....	.029	.0067	.0135	.0068	20.0	.027	.35	2.4	0	61	0.12	47	7.5	14.5	89.3
Average	.0305	8.8	51	.030	.0072	.0138	.0066	62.0	.047	.23	7.4	266	127	.....	.....	4.4	14.7	95.5

Table 19.—Continued—Group II—.0370 to .0740.—Parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen er cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
968	.0594	15.8	96	.075	.0110	.0197	.0087	81.5	.069	1.06	12.5	0	232	10–36	4	1.8	23.5	107.2
1135	.0467	11.5	75	.020	.0100	.0194	.0094	26.5	.035	.07	2.0	0	216	0–12	4	4.8	21.5	126.5
937	.0727	13.5	54	.016	.0150	.0147	.0003	7.3	.030	.12	2.9	0	270	0–12	4	11.2	41.2	139.4
9331	.0614	17.5	.....	.049	.0075	.0187	.0112	41.0	.034	.22	0.8	0	62	0–10	47	15.7	28.1	74.9
3611	.0437	8.5	84	.025	.0105	.0178	.0073	75.2	.046	.27	1.2	0	83	0–10	13	6.5	18.1	84.0
2350	.0514	9.4	92	.016	.0098	.0168	.0070	35.2	.014	.11	2.0	200	86	0–12	13	8.4	29.6	148.9
5969	.0659	10.0	59	.087	.0045	.0170	.0125	34.5	.036	.05	3.5	0	60	12–24	13	9.6	36.6	137.7
3400	.0649	10.2	49	.080	.0080	.0213	.0133	78.0	.077	.32	7.7	200	64	9–21	14	6.9	27.1	123.7
4187	.0692	14.7	93	.030	.0108	.0195	.0087	88.5	.077	.41	12.1	0	54	12–24	14	9.6	29.6	63.4
6884	.0610	12.5	72	.020	.0067	.0155	.0088	14.9	.040	.15	1.5	0	183	0–12	14	15.2	34.4	149.8
4291	.0742	41.9	308	.065	.0360	.0665	.0305	73.4	.041	15.11	100.0	0	140	0–12	17	13.0	37.4	45.8
7255	.0394	6.9	53	.045	.0043	.0135	.0092	50.5	.052	.16	1.0	0	116	6–10	29	7.6	17.8	111.2
7121	.0504	6.8	65	.069	.0054	.0120	.0066	84.2	.080	.51	10.0	0	109	12–24	29	7.9	27.1	124.3
7238	.0604	7.5	.....	.025	.0061	.0097	.0036	60.1	.045	.35	3.0	.....	65	12–24	29	9.7	31.8	109.0
7242	.0471	8.7	61	.016	.0058	.0113	.0058	8.6	.025	.22	1.4	200	45	7–19	29	10.5	26.8	87.7
7251	.0686	6.2	62	.028	.0145	.0174	.0029	37.6	.044	.15	1.9	0	41	6–18	29	13.3	37.6	122.7
7154	.0413	10.6	57	.026	.0053	.0122	.0069	23.5	.029	.13	1.5	0	148	8–20	30	9.5	20.0	97.6
4650	.0386	21.2	47	.069	.0130	.0250	.0120	75.5	.075	.....	13.4	300	.....	.....	30	10.0	21.8	79.1
7150	.0484	11.5	49	.016	.0105	.0178	.0073	33.0	.....	.70	1.5	0	46	6–18	30	14.2	24.8	64.4
1200	.0588	10.5	44	.044	.0175	.0210	.0035	1.7	.023	.06	2.0	0	70	0–15	30	16.0	24.2	64.7
9187	.0577	32.8	128	.046	.0104	.0290	.0186	36.5	.089	.65	13.2	0	143	0–11	36	7.2	29.4	135.6
9314	.0422	10.6	43	.032	.0065	.0160	.0095	79.0	.063	1.09	20.0	0	108	6–18	47	3.4	20.5	86.2
9168	.0699	17.5	.....	.064	.0165	.0388	.0223	46.5	.068	.26	5.0	.....	230	5–13	47	8.9	33.1	97.6
9353	.0598	11.9	.....	.037	.0078	.0512	.0134	22.5	.081	.16	2.5	460	81	0–12	47	12.7	33.1	143.2
9277	.0811	19.0	.....	.049	.0073	.0220	.0127	56.3	.059	.82	16.2	0	268	0–7	47	24.2	45.5	77.9
Average	.0577	13.5	79	.041	.0104	.0217	.0101	46.9	0.051	0.96	9.6	59	122	.....	.....	13.5	28.8	101.5

Table 19—Continued.—Relation of crops to analyses. Group III.—.0740 to .1054—parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
992	.0811	15.0	48	.117	.0110	.0197	.0087	61.5	.040	1.06	7.6	0	232	10–36	4	6.7	33.2	98.9
1137	.0977	13.5	67	.024	.0173	.0240	.0067	34.0	.050	.12	7.0	0	178	0–7	4	9.8	50.3	148.8
913	.0893	18.7	64	.020	.0109	.0201	.0092	25.0	.040	.12	1.0	0	231	0–10	4	14.8	45.9	114.4
5967	.0800	15.6	580	.160	.1010	.1230	.0220	90.7	.098	16.00	99.4	0	61	10–18	14	11.5	39.1	98.7
7120	.0767	9.0	65	.024	.0080	.0175	.0095	59.5	.110	.32	4.3	0	109	0–12	29	11.5	40.7	112.4
7224	.1021	12.5	309	.092	.0542	.0865	.0323	86.1	.096	20.24	100.0	0	148	12–24	30	12.0	49.8	84.8
7162	.0931	11.2	54	.048	.0110	.0305	.0195	81.9	.168	1.24	25.3	0	180	12–20	30	12.2	42.2	104.8
7181	.0932	11.2	459	.117	.0760	.1165	.0405	85.6	.170	20.44	99.0	0	85	0–11	30	15.9	43.4	92.3
7233	.0822	18.1	.....	.022	.0105	.0175	.0070	6.1	.043	.32	1.5	0	68	0–6	30	17.6	32.6	82.2
7254	.0816	17.2	53	.020	.0088	.0200	.0112	15.2	.048	.60	1.0	0	146	0–7	30	22.7	42.1	107.7
7244	.1025	17.8	93	.018	.0090	.0163	.0073	17.9	.038	.16	1.2	200	51	0–14	30	25.2	43.7	109.5
9333	.1010	21.9	105	.040	.0087	.0155	.0068	38.0	.028	.28	2.7	230	141	0–12	36	20.1	47.2	134.3
9311	.1016	23.1	.....	.036	.0180	.0300	.0120	20.0	.033	.38	1.6	0	114	0–8	36	20.6	53.9	131.1
9183	.0874	14.1	.....	.032	.0110	.0265	.0155	17.9	.039	.15	3.5	0	114	0–12	47	11.0	39.3	115.9
9305	.1062	29.4	63	.038	.0065	.0150	.0085	15.0	.060	.38	0.5	230	60	0–12	36	22.7	54.0	128.5
9279	.0714	15.6	.....	.026	.0058	.0105	.0047	8.0	.032	.17	1.7	0	103	0–12	47	19.5	42.2	121.7
Average	.0904	16.5	163	.052	.0230	.0368	.0138	41.4	.068	3.87	22.3	50.7	126	.....	.....	15.2	42.7	111.7

Table 19—Continued.—Relation of crops to analyses. Group IV.—.1054 to .1358—parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
2944	.1197	19.5	75	.028	.0133	.0258	.0125	61.9	.120	.59	11.2	0	175	0–12	4	17.6	61.4	153.2
5944	.1092	6.2	69	.050	.0145	.0185	.0040	60.1	.049	.13	3.5	0	126	9–21	13	15.8	60.0	118.0
5710	.1394	10.6	80	.060	.0090	.0185	.0095	26.0	.070	.21	4.5	0	76	0–12	13	19.3	66.9	149.8
6680	.1077	19.4	72	.041	.0088	.0248	.0160	52.5	.120	.....	3.0	800	105	0–7	14	15.7	57.0	177.7
894	.1568	18.2	119	.045	.0188	.0470	.0282	29.0	.070	.06	3.2	464	.....	0–6	14	34.6	75.3	133.8
7240	.1259	42.5	142	.039	.0177	.0317	.0140	27.6	.024	.38	1.0	200	81	8–20	27	12.6	49.0	105.9
6882	.1059	45.6	91	.038	.0200	.0340	.0140	56.5	.084	2.32	40.6	0	281	0–6	27	12.7	52.2	100.9
7252	.1112	45.0	67	.025	.0145	.0260	.0115	11.4	.029	.10	0.8	0	81	0–5	27	22.5	37.1	76.4
7241	.1341	31.2	54	.038	.0087	.0150	.0063	10.4	.077	.17	2.4	0	132	0–7	28	23.7	64.4	116.8
7266	.1060	19.4	.....	.030	.0110	.0180	.0070	23.3	.064	.17	7.0	0	221	14–24	30	5.0	27.5	40.4
5956	.1159	18.7	62	.034	.0130	.0275	.0145	95.1	.092	.95	17.4	0	694	.....	30	9.0	53.1	115.9
7228	.1195	16.2	141	.031	.0095	.0200	.0105	59.7	.059	41	9.6	0	79	12–24	30	18.0	51.5	89.6
7118	.1351	22.6	94	.068	.0390	.0590	.0200	60.5	.089	9.17	100.0	0	110	0–10	30	22.6	60.6	97.7
7237	.1171	18.7	85	.035	.0080	.0330	.0250	46.7	.111	.27	3.5	200	74	0–12	30	24.7	66.2	134.2
7346	.1063	20.0	.....	.022	.0093	.0154	.0061	34.6	.026	.22	0.5	230	76	5–15	36	15.1	44.3	101.0
7374	.1125	68.7	126	.083	.0480	.0650	.0170	50.2	.122	9.97	99.5	.....	163	6–12	36	22.5	63.4	127.3
9378	.1250	28.8	.....	.040	.0113	.0235	.0122	18.5	.090	0.15	3.2	0	93	0–7	36	28.5	64.1	137.7
Average	.1204	26.5	90	.047	.0162	.0296	.0134	42.6	.076	1.58	18.3	118	154	.....	.....	18.8	56.1	116.2

Table 19—Continued.—Relation of crops to analyses. Group V.—.1358 to .1658—parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
895	.1363	27.5	72	.022	.0115	.0178	.0063	13.8	.060	.18	3.0	300	168	0–12	4	28.3	69.0	134.0
2353	.1408	51.2	168	.025	.0152	.0270	.0118	22.0	.021	.12	1.5	.....	103	7–22	17	15.4	92.2	150.3
936	.1601	55.0	138	.030	.0183	.0225	.0042	5.3	.030	.17	2.9	0	326	0–12	17	32.1	84.6	124.2
970	.1359	45.0	105	.029	.0165	.0287	.0122	67.2	.060	.50	9.6	0	409	12–36	27	5.0	68.8	127.0
7169	.1506	44.5	.....	.057	.0130	.0308	.0178	24.0	.056	.30	1.3	.....	153	0–6	27	24.3	65.3	122.1
6883	.1542	56.9	155	.036	.0158	.0360	.0202	55.3	.095	1.84	31.6	0	241	6.18	27	24.5	83.7	129.5
7265	.1491	48.7	109	.017	.0108	.0160	.0052	9.7	.036	.09	0.9	0	123	0–14	27	38.5	78.0	116.0
5954	.1574	31.6	738	.081	.....	.....	.....	80.4	.160	24.90	100.0	0	76	6–18	28	13.7	73.1	112.2
6976	.1579	35.6	112	.043	.0200	.0305	.0105	37.5	.068	.70	5.5	0	275	0–10	28	24.7	74.5	151.8
7145	.1491	14.4	281	.071	.0390	.0613	.0223	78.2	.098	15.93	100.0	0	135	0–12	30	24.7	67.1	102.9
7708	.1543	22.5	55	.032	.0074	.0212	.0138	42.9	.138	.57	9.3	0	86	0–6	36	15.6	75.6	106.6
7341	.1599	22.2	96	.038	.0108	.0257	.0147	57.5	.105	1.49	25.2	0	161	0–7	36	18.4	71.2	78.9
Average	.1505	37.9	184	.040	.0162	.0289	.0126	27.4	.077	3.90	24.2	0	188	.....	.....	22.1	75.3	121.3

Table 19—Continued.—Relation of crops to analyses. Group VI.—Over .1658—parts per million per crop.

	Crops grams phosphoric acid	Phosphoric Acid							Nitrogen per cent	Lime per cent	Acid consumed per cent	Acidity per million	Active potash per million	Depth inches	Series No.	Weight first crop grams	Weight of four crops grams	Weight of four crops KPN grams
		Active per million	Extract 5 times per million	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent	Absorbed per cent										
4186	.1910	20.0	106	.068	.0183	.0443	.0260	90.1	.210	.55	11.7	0	144	0–12	14	12.6	72.5	101.6
3333	.1766	20.0	99	.021	.0117	.0213	.0096	22.7	.034	.17	3.4	0	155	0–10	14	32.8	91.8	137.8
5945	.1736	48.7	120	.038	.0145	.0265	.0120	10.6	.038	.09	1.5	0	84	0–8	17	35.9	94.8	131.1
5943	.2398	53.8	141	.057	.0160	.0302	.0142	19.2	.050	.24	3.0	0	155	0–9	17	45.9	122.6	150.0
5100	.2206	60.6	122	.022	.0145	.0258	.0113	9.4	.027	.21	2.0	0	179	0–11	17	48.7	120.4	149.4
7107	.2457	41.2	99	.030	.0117	.0230	.0113	87.1	.065	.63	12.0	0	143	7–19	.....	147.2	418.0	96.7
7159	.1913	43.7	105	.033	.0107	.0175	.0068	32.7	.045	.23	3.7	0	129	0–8	27	28.5	86.1	124.0
7225	.2378	49.6	106	.040	.0148	.0192	.0044	36.9	.029	.15	0.5	0	126	0–9	27	29.4	87.5	100.5
5958	.2068	32.5	78	.056	.0210	.0390	.0180	80.4	.132	1.04	21.8	0	440	9–21	28	27.2	98.7	145.1
5966	.2669	31.2	971	.190	.1162	.1553	.0391	85.8	.176	12.68	100.0	0	178	0–10	28	32.9	115.5	132.4
7227	.2045	38.7	116	.034	.0160	.0218	.0058	52.1	.090	.39	7.5	0	66	0–12	28	41.0	99.5	136.5
5953	.5339	48.0	917	.217	.1330	.1980	.0543	74.9	.240	18.15	100.0	0	266	0–6	28	41.4	153.2	170.9
5957	.3886	30.0	96	.056	.0147	.0375	.0128	80.4	.132	1.07	23.8	0	588	0–9	28	43.5	151.3	140.8
2828	.1760	17.6	62	.117	.0248	.0645	.0397	36.2	.152	.82	20.2	0	308	0–6	30	11.9	76.6	99.4
Average	.2466	38.3	224	.070	.0313	.0517	.0189	51.3	.101	2.60	22.2	0	211	.....	.....	41.3	127.8	129.7

Table 20.—Average composition of soils arranged according to phosphoric acid taken by four crops.

	Phosphoric acid 4 crops	No. of soils	Phosphoric Acid						Nitrogen per cent	Lime per cent	Acid consumed	Active potash per million	No. of sub soils
			Active per million	Five extracts	Total per cent	Acid Sol. per cent	After ignition per cent	Ignition Sol. per cent					
Group 1	0.0305	11	8.8	51	0.030	0.0072	0.0138	0.0066	0.047	0.23	7.4	127	10
Group 2	0.0577	24	13.5	79	0.041	0.0104	0.0217	0.0101	0.051	0.96	9.6	122	13
Group 3	0.0904	16	16.5	163	0.052	0.0230	0.0368	0.0138	0.068	3.87	22.3	126	4
Group 4	0.1200	18	26.5	90	0.047	0.0162	0.0296	0.0134	0.076	1.58	18.3	154	6
Group 5	0.1505	12	37.9	184	0.040	0.0162	0.0289	0.0126	0.077	3.90	24.2	188	4
Group 6	0.2466	14	38.3	224	0.070	0.0313	0.0517	0.0189	0.101	2.60	22.2	211	2

Group No. 4, from .1055 to .1358 grams or 6.8 parts per million per crop.

Group No. 5, from .1359 to .1658 grams or 8.4 parts per million per crop.

Group No. 6, over .1658 grams phosphoric acid removed by four crops.

The individual soils are shown in Table 19. The average results of this arrangement are given in Table 20.

The active phosphoric acid increases regularly with the average phosphoric acid taken up by the four crops. The difference between group 5 and group 6 is not great, however. The total phosphoric acid is lowest for the first group and highest for the last group, but groups 2, 3, 4, and 5 contain nearly the same quantities of total phosphoric acid. The acid consumed is lowest in the first two groups, but is then irregular.

The nitrogen increases regularly from the first group to the sixth group, with the exception of group 5. It has already been pointed out that in soils containing the same amount of active phosphoric acid, the plants seem to take up more phosphoric acid from the soils containing more nitrogen. The relation is not regular. The lime is lowest for the first group and is then irregular. The acid-soluble phosphoric acid increases regularly with the first three groups, and is highest with the sixth group, but groups 4 and 5 are irregular. The phosphoric acid dissolved after ignition, like the acid-soluble phosphoric acid increases with the first three groups, and is highest with the sixth group, but is irregular with groups 4 and 5. The ignition-soluble phosphoric acid increases up to the sixth group, with the exception of group 5, but the difference between groups 3 and group 4 is very slight. The proportion of subsoils is largest in the first group, next largest in the second, and is about the same for groups 3, 4 and 5. It is smallest in group 6.

There is a closer relation between the active phosphoric acid and the results of the pot experiments, than between any other constituent and the pot experiments. Some of these relations may be incidental, and some may be associated with other properties of the soil.

THE RELATION OF THE ACTIVE PHOSPHORIC ACID, AND THE TOTAL PHOSPHORIC ACID TO THE NEEDS OF THE SOIL FOR PHOSPHORIC ACID.

It was pointed out in Bulletin 126 that the active phosphoric acid is related to the needs of soil for phosphoric acid in pot experiments. While the object of this bulletin is to ascertain if possible the reason why somewhat wide differences occur between soils containing the same quantities of active phosphoric acid, it is well, however, to point out the relation between the active phosphoric acid, the total phosphoric acid, and the needs of the soil for phosphoric acid, as shown in the results of the pot experiments presented in this bulletin.

Table 21 gives the relation between the average active phosphoric acid and the parts per million of phosphoric acid removed by crops. The two run closely parallel, with the exception of group 6, which does not contain as much active phosphoric acid as it should. The percentage of total phosphoric acid removed by four crops increases from group to group. It is lowest with the first group and increases up to the fifth group. Apparently the availability of the active phosphoric acid varies, since a greater amount of phosphoric acid is removed from

Table 21.—Relation between phosphoric acid in soil and removed by crops.

	Parts per million		Per cent Total Phosphoric Acid in soil	Per cent Total Removed by four crops
	Active in soil	Removed by four crops		
Group 1	8.8	6.1	.030	2.0
Group 2	13.5	11.5	.041	2.7
Group 3	16.5	18.1	.052	3.5
Group 4	26.5	24.1	.047	5.1
Group 5	37.9	30.1	.040	7.5
Group 6	38.3	49.3	.070	7.0

the soil by the crops, when larger amounts of active phosphoric acid are present.

Table 22 shows the average relations when the soils are arranged in groups according to the total phosphoric acid present. The active phosphoric acid is lowest with group 1 and highest with group 5, but groups 2, 3, and 4 are nearly the same. The first crops increase regu-

Table 22.—Average relation of total phosphoric acid to results of pot experiments.

	Number averaged	Phosphoric Acid		Weight of		Phosphoric Acid, gms. removed by four crops
		Total per cent	Active per million	First crop, gms.	Four crops, gms.	
Group 1—Below .020 per cent. total	12	.017	15.9	14.6	34.4	.0673
Group 2—.021–.040 per cent.	46	.038	22.5	19.5	59.4	.1085
Group 3—.041–.060	17	.049	22.7	21.2	60.0	.1286
Group 4—.061–.080	10	.060	17.4	11.3	38.8	.0869
Group 5—Over .080	10	.126	26.1	17.8	68.5	.1669

larly with groups 1, 2, and 3, but group 4 is the lowest, and group 5 is less than group 2. The total weights of four crops is lowest with group 1, group 2 is a little larger, group 3 nearly the same as group 2, group 4 less than group 2, and group 5 is highest. The phosphoric acid removed by four crops increases regularly, with the exception of group 4. There is some relation between the total phosphoric acid and the results of the pot experiments.

Figure 1 shows the relation between the active phosphoric acid of each soil, and the phosphoric acid removed by four crops from it. Each soil is represented by a dot and the position of the dot shows the amount of active phosphoric acid contained in it, and the amount of phosphoric acid removed by the crops. The figure shows that there is a relation between the active phosphoric acid, and the phosphoric acid removed by the crops.

Figure 2 represents the relation between the total phosphoric acid and the phosphoric acid removed by the crops in the same way. The relation is better for the active than for the total phosphoric acid.

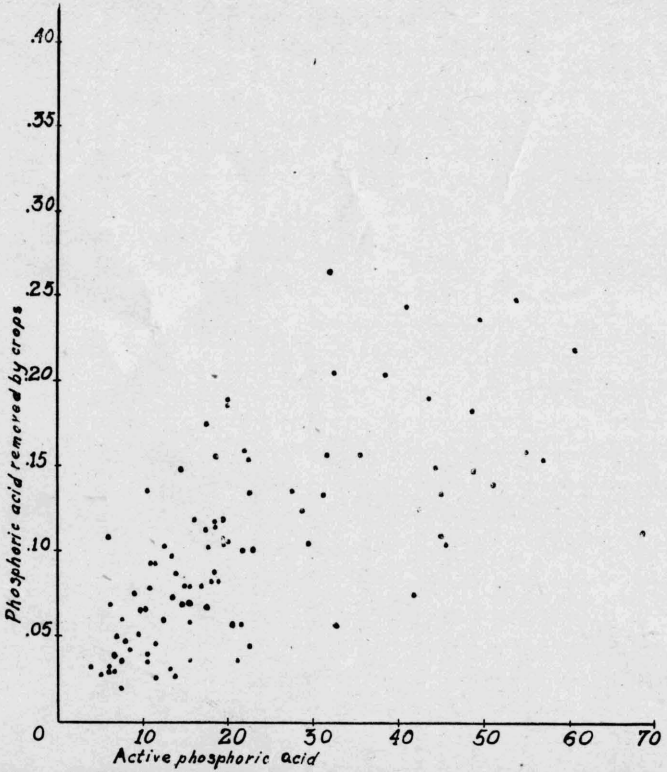

Figure 1—Relation of active phosphoric acid of the soil to the phosphoric acid withdrawn by four crops.

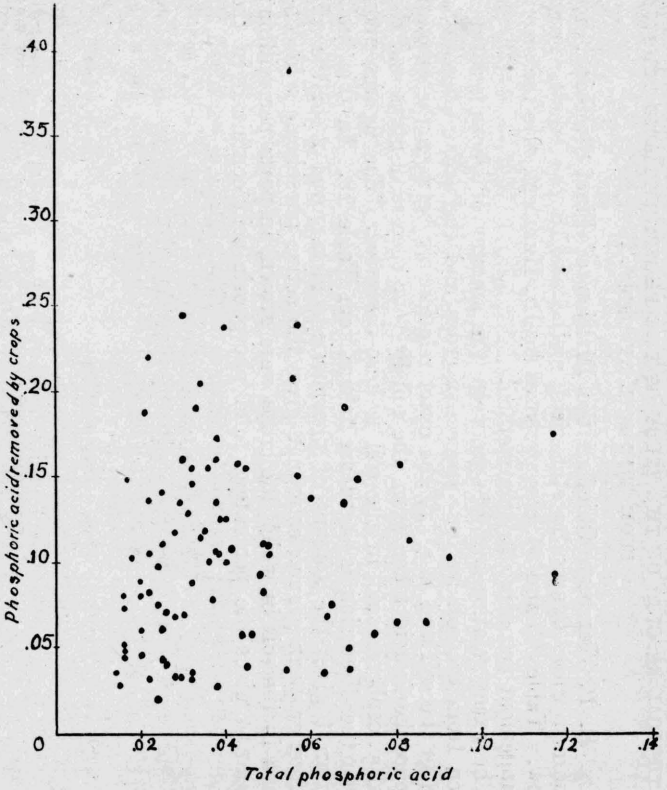

Figure 2—Re'ation of the tota' phosphoric acid of the soil to the phosphoric acid withdrawn by four crops.

STATISTICAL RESULTS OF THE STUDY OF THE PHOSPHORIC ACID REMOVED FROM THE SOIL BY CROPS.

Dr. E. P. Humbert, Chief of the Division of Plant Breeding, has examined these figures by statistical methods with the results given below. Tables 23 and 24, also prepared by Dr. Humbert, give the group arrangement according to this method.

The exact relationship (1) between the amount of phosphoric acid taken from the soil by four successive crops and the active phosphoric acid in the soil and also (2) the exact relationship between the amount of phosphoric acid taken from the soil by four successive crops and the total phosphoric acid in the soil is here discussed. The figures upon which the discussion is based are taken from Table 19. In this table column 1 gives the amount of phosphoric acid removed from the soil by four crops in grams; column 2 gives the active phosphoric acid contained in the soil in which the crops were grown, in parts per million; column 4 gives the percentage total phosphoric acid contained in the soil.

RELATIVE.

Total Phosphoric Acid in Soil in Per Cent.

SUBJECT. Amount of Phosphoric Acid Taken by Four Crops in Grams.	.01 – .019	.02 – .029	.03 – .039	.04 – .049	.05 – .059	.06 – .069	.07 – .079	.08 – .089	.09 – .099	.10 – .109	.11 – .119	.12 – .129	.13 – .139	.14 – .149	.15 – .159	.16 – .169	.17 – .179	.18 – .189	.19 – .199	.20 – .209	.21 – .219	
.02 – .04	4	9	2	1	1	2																19
.05 – .07	1	6	2	2		3	1	2														17
.08 – .10	1	5	5	4	1				1		2					1						20
.11 – .13		4	5	2		2		1														14
.14 – .16	1	1	3	3	1		1	1														11
.17 – .19		1	2			1					1											5
.20 – .22		1	1		1																	3
.23 – .25			1	1	1																	3
.26 – .28																			1			1
.29 – .31																						0
.32 – .34																						0
.35 – 37																						0
.38 – .40					1																	1
.41 – .43																						0
.44 – .46																						0
.47 – .49																						0
.50 – .52																						0
.53 – .55																					1	1
	7	27	21	13	6	8	2	4	1	0	3	0	0	0	0	1	0	0	1	0	1	95

Table 24.—Correlation Table (Humbert).

RELATIVE.

Active Phosphoric Acid in Soil in Parts per Million.

SUBJECT. Amount of Phosphoric Acid Taken by Four Crops in Grams.	3 – 6	7 – 10	11 – 14	15 – 18	19 – 22	23 – 26	27 – 30	31 – 34	35 – 38	39 – 42	43 – 46	47 – 50	51 – 54	55 – 58	59 – 62	63 – 66	67 – 70	
.02 – .04	6	6	5	1	1													19
.05 – .07	2	6	4	3				1		1								17
.08 – .10	1		5	6	5	1	1				1							20
.11 – .13		1		4	2		2	1		1	2						1	14
.14 – .16			1	1	2			1	1		1	1	1	2				11
.17 – .19				1	2						1	1						5
.20 – .22								1	1						1			3
.23 – .25										1		1	1					3
.26 – .28								1										1
.29 – .31																		0
.32 – .34																		0
.35 – .37																		0
.38 – .40							1											1
.41 – .43																		0
.44 – .46																		0
.47 – .49																		0
.50 – .52																		0
.53 – .55												1						1
	9	13	15	16	12	1	4	5	2	3	5	4	2	2	1	0	1	95

The statistical constants for the three columns considered as populations and arranged for frequency distribution are as follows:

Amount of Phosphoric Acid Removed From the Soil by Four Successive Crops.

N=95.
Mode=.095 grams.
Modal coefficient=21.05 per cent.
Mean=.1120±.0054 grams.
Standard deviation=.0779±.0038 grams.
Coefficient variability=69.57±4.77 per cent.

Active Phosphoric Acid in the Soil.

N=95.
Mode=17 parts per million.
Modal coefficient=16.84 per cent.
Mean=22.64±1.059 parts per million.
Standard deviation=15.31±.7490 parts per million.
Coefficient of variability=67.48±.5903 per cent.

Total Phosphoric Acid in the Soil.

N=95.
Mode=.025 parts per hundred.
Modal coefficient=28.42 per cent.
Mean=.0468±.0023 parts per hundred.
Standard deviation=.0345±.0017 parts per hundred.
Coefficient of variability=73.57±5.194 per cent.

Relationship Between the Amount of Phosphoric Acid Removed from the Soil and the Active Phosphoric Acid in the Soil.

Correlation coefficient=.5656±.0471.

Relationship Between the Amount of Phosphoric Acid Removed by Four Successive Crops from the Soil and the Total Phosphoric Acid in the Soil.

Correlation coefficient=.4495±.0552.

The constants may be better interpreted by brief definitions as follows:

N=the number of analyses which make up each column of figure or population.

Mode=the type or the value into which the greatest number of the analyses fall.

Modal coefficient=the per cent. of the type number to the total population.

Mean=average value of all of the analyses.

Standard deviation=the deviation of the analyses from the mean value.

Coefficient of variability=the relation of the standard deviation to the mean.

Correlation coefficient=the relation which exists between two populations. In a perfect positive correlation the coefficient equals +1. In a perfect negative correlation the coefficient equals —1. For instance, if the soils with high content of phosphoric acid always

gave up more phosphoric acid to the four crops than soils of lower content of phosphoric acid the correlation coefficient would be +1. If the soils with high phosphoric acid content always gave up less phosphoric acid to the four crops than soils of lower content of phosphoric acid the correlation coefficient would be —1.

The relationship sought, then, lies between +1 and —1 as .57 for the relationship between removal and active content and .45 for the relationship between removal and total content.

The relationship is closer between the active phosphoric acid and removal than it is with total phosphoric contents. The correlation coefficient is higher.

PHOSPHORIC ACID DISSOLVED BY SUCCESSIVE EXTRACTIONS

The quantity of phosphoric acid expressed in parts per million extracted in five successive extractions with fifth-normal nitric acid, was estimated on a number of the soils. The figures for each soil is given in Table 19 and the average composition compared with crop production in Table 11, while Table 20 shows the average by groups arranged according to the phosphoric acid taken up by the crops.

There does not seem to be any relation between the active phosphoric extracted by five extractions, and the relative production within the groups arranged according to the active phosphoric acid, as given in Table 12. The soils with low phosphoric acid have a low phosphoric acid removed by five extractions, as might be expected.

The phosphoric acid taken up by five extractions does not come in as close relation with the phosphoric acid taken from the soil by crops, as seen in Table 19, as does the active phosphoric acid taken up by one extraction.

Some of the soils studied contain so much lime that it neutralized all of the acid used in the first extraction. With these soils, the acid consumed is 100 per cent. Usually a soil extracted several successive times with fifth-normal nitric acid, gives the largest quantity to the first extraction and smaller amounts of phosphoric acid to successive extractions. If the amount of active phosphoric acid is high, the amount given to the successive extractions usually falls off rapidly. When the soil contains about 10 parts per million of active phosphoric acid, the successive extractions contain nearly the same amount of phos-

Table 25.—Successive extractions of active phosphoric acid in parts per million.

Extraction	1	2	3	4	5	Total
335	6	9	9	8	8	40
4234	5	12	9	11	7	44
9305	28	10	8	7	9	63
9333	22	27	18	22	16	105
7252	45	21	9	9	7	91
7240	43	28	21	19	8	119
4291	42	37	166	50	13	308
5967	16	12	445	33	74	580
7224	13	9	41	207	39	309
7181	11	12	183	161	82	459
7118	23	18	59	24	17	141
5954	32	72	256	256	122	738
7145	14	11	114	78	64	281
5966	31	36	571	231	102	971
5953	48	61	425	221	162	917

phoric acid. When the soil contains enough lime to neutralize all of the nitric acid in the first extraction, the amount of phosphoric acid extracted is small with this first extraction, and reaches a maximum with the first extract which does not consume all the nitric acid.

Examples of this are given in Table 25. The phosphoric acid extracted by five extractions from soils high in lime is often very much greater than the amounts extracted from soils which do not contain so much lime.

Table 26 shows, in the second column, the average amount of phosphoric acid extracted by five extractions, when the soils which use up all of the acid on the first extraction are excluded. The average amounts of phosphoric acid are much lower, but there is still no close relation

Table 26.—Active phosphoric acid removed by five extractions, parts per million.

	All soils	Soil containing less than 5.6% lime	Number excluded.
Series 4, 14, 30, 47, below 25 per cent	95	60	1
Within 25 per cent	116	65	1
Over 25 per cent	103	81	2
Series 28, below 25 per cent	266	90	1
Within 25 per cent	389	97	1
Over 25 per cent	535	96	1
Series 17, 27, below 25 per cent	174	115	1
Group 1	53	53	0
Group 2	78	67	1
Group 3	158	57	3
Group 4	90	87	1
Group 5	173	111	2
Group 6	228	104	2

to be traced with these results and the results of the pot experiments. The average amount extracted is lowest with the soils which, in the same group, produce the least, and highest with those which produce the most. The difference in one series is very little.

When the arrangement is into groups of soils which give up equal amounts of phosphoric acid to plants, there are decided changes in the amount of phosphoric acid removed by five extractions, but the relation between the six groups is still not regular (see Table 19). There is a nearer approach to regularity than when the limestone soils of this character are included.

CORRECTION OF ACID FOR LIME REMOVED.

The preceding discussion brings up the question whether or not the strength of the acid should be corrected for the amount of bases removed, as required by the methods of the Association of Official Agricultural Chemists. Dyer did not believe that such corrections should be made, as he considered this was a condition that the plants had to meet in dissolving the phosphoric acid by means of the acidity of the roots. This laboratory does not correct the acid for lime removed.

The amount of phosphoric acid removed when the acid is corrected was not determined in this work, but the behavior of the soil to five successive extractions with nitric acid throws some light upon the subject. As just pointed out, with most soils, the first extract is the largest,

and the amount of phosphoric acid in the other extracts decreases. With the limestone soils, containing over 5.6 per cent. of bases equivalent to lime, the first extract is smaller, and the largest amount of phosphoric acid is removed by the first extract which does not neutralize all the lime. If the acid is corrected for the lime neutralized, there would be a great increase in the amount of active phosphoric acid extracted, and in such case these soils should belong in much higher groups in respect to their active phosphoric acid than the ones in which we have placed them.

Table 27 shows the relation of the phosphoric acid contained in soils high in lime to the average phosphoric acid of the groups in which they were placed, based upon the amount of phosphoric acid removed from them by crops. For six of the nine soils, the active phosphoric acid is near to the average of the group. With soil 4291, the active phosphoric acid is 41.9 parts per million, while the average for group 2 is 13.7 parts per million, so that this soil did not give up as much phosphoric acid as the active phosphoric acid content would lead us to expect. Soil 7145 in group 5 contains 14.4 parts per million of active phosphoric acid, and gives up more phosphoric acid to crops than we would expect. Soil 5953 gave up the largest quantity of active phos-

Table 27.—Relation of soils high in lime to other members of groups based on phosphoric acid removed by crops.

	In four crops, grams	Active Phosphoric Acid per million	Active Phosphoric Acid in five extracts	Active Phosphoric Acid when corrected
Average Group 2	.0577	13.5	79	.....
Soil No. 4291	.0742	41.9	308	.....
Average Group 3	.0904	16.5	163	.....
Soil No. 5967	.0800	15.6	580	.....
Soil No. 7224	.1021	12.5	309	.....
Soil No. 7181	.0932	11.2	459	.....
Average Group 4	.1204	26.5	90	.....
Soil No. 7118	.1351	22.6	94	.....
Average Group 5	.1505	37.9	184	.....
Soil No. 5954	.1524	31.6	738	673
Soil No. 7145	.1491	14.4	281	.....
Average Group 6	.2466	38.3	224	.....
Soil No. 5966	.2669	31.2	971	.....
Soil No. 5953	.5339	48.0	917	775

phoric acid to the crops in these experiments. It contains more than the average for the group. On the other hand, if the phosphoric acid removed by five extractions is considered, much larger quantities are removed from the soils rich in lime than the averages for the groups in which they are placed from crop results. There is thus a closer relation between the active phosphoric acid when the correction is not made for bases neutralized, than there would be if the correction were made. It is probable that such a correction would place the nine soils out of harmony with the other soils of the groups in which they are placed from the amount of the phosphoric acid removed by four crops.

The active phosphoric acid was determined with the correction for acid neutralized in soils 5954 and 5953. The amount found was 673

parts per million in one case, and 775 in the other. These amounts would place these soils far out of relation with other soils in the groups in which they are placed on account of the phosphoric acid removed by four crops.

DISCUSSION OF INDIVIDUAL SOILS.

We now propose to discuss some of the individual soils, to see if there is anything in their chemical composition which, taken in connection with their active phosphoric acid, places them in a higher group, or a lower group, than their content of active phosphoric acid would apparently warrant. In this discussion we can bear in mind what has been brought out in this and previous bulletins; namely, that the addition of carbonate of lime, or organic matter, sometimes increases the amount of phosphoric acid which plants can take up from the soil; that soils which absorb a high per cent of phosphoric acid may contain more active phosphoric acid than the analysis shows; that lime or other material soluble in acid may surround particles of phosphates, and protect them from the action of plant roots; that there is a tendency for soils containing the same amount of active phosphoric acid to give up more phosphoric acid to plants when they contain more than the average amounts of nitrogen, and of total phosphoric acid.

In this discussion, we will consider the soils arranged in groups according to the active phosphoric acid taken up from them by crops. (Table 19).

In group 1 (11 soils), the lowest amount of active phosphoric acid is 3.8, and the highest 15.6 per million. There are eight soils containing less than 10 parts per million of active phosphoric acid and four containing more than 10 parts. There are two soils containing much more than the average amount of total phosphoric acid and one containing much more than the average in nitrogen. We might expect these soils to do better than they do.

The variation of the soils of this group in active phosphoric acid is comparatively small. There is nothing in the analysis to show why the three soils containing more than 12 parts per million of active phosphoric acid gave up less phosphoric acid to the crops than soils of group 2, to which they would belong on the basis of their active phosphoric acid. The total crop produced on these soils with a complete fertilizer is much less than the average.

Group 2 (25 soils) contains two soils with a high active phosphoric acid, soil 4291 with 41.9 parts per million and soil 9187 with 32.8. Soil 4291 is high in lime, and this may protect some of the phosphoric acid from the roots of the plants, and thereby place the soil in a lower group than it would appear to belong. Soil 9187 does not contain nearly the same amount of lime, but the same possibility exists. There are seven soils in this group which contain less than 7 parts per million of active phosphoric acid. Four of these are higher than the average in total phosphoric acid, and one is higher than the average in total nitrogen. These are the only indications why the soils should perform better than the soils of group 1, in which their active phosphoric acid would place them. Seven soils contain more than the average total phosphoric acid, of which three are lower than the average in active, and four may contain enough lime to protect phosphates from plant roots.

Group 3 contains 16 soils varying from 9.0 to 29.4 parts per million of active phosphoric acid. The average of the group is 16.5. The soil

containing 9.0 parts per million of active phosphoric acid is low in total phosphoric acid, but high in nitrogen. The three soils containing less than 12 parts per million of active phosphoric acid are high in nitrogen, and two of them are also high in total phosphoric acid. Active phosphoric acid seems to be more effective when associated with nitrogen greater than the average.

Three soils in this group contain more than 22 parts per million of active phosphoric acid. They, therefore, do not perform as well as one would expect from their content of active phosphoric acid. They all contain less than the average in total phosphoric acid and two are lower than the average in nitrogen. Two of them are acid. Four soils in this group are high in total phosphoric acid, two of which are low in active and all of which contain much lime.

Group 4 contains 17 soils varying from 6.2 to 68.7 parts per million of active phosphoric acid, with an average of 26.5. One soil contains 6.2 parts per million, and another 10.6. These contain more total phosphoric acid than the average of Group 1. One is a subsoil and the other a surface soil. There is nothing in the analysis except the total phosphoric acid to show why the soils should perform better than one would expect from their content of the active phosphoric acid.

Four soils in this group contain over 40 parts per million of active phosphoric acid. Two of these soils are rich in lime, and the phosphate may be protected from the action of the plant roots by lime. Three are low in total phosphoric acid; though high in active.

Group 5 contains 12 soils varying from 14.4 to 56.9 in active phosphoric acid, with an average of 37.9 parts per million. There are three soils with less than 25 parts per million of active phosphoric acid. Two of these soils are rich in lime, and the phosphoric acid may be protected by carbonate of lime from the action of roots. The third soil is low in lime and total acid, but high in nitrogen.

Two soils contain over 55 parts per million of active phosphoric acid, and are low in total phosphoric acid. One is low in lime, and the other is above the average. One is a surface soil, and the other is subsoil.

Group No. 6 contains 14 soils varying from 20 to 60 parts per million of active phosphoric acid, and the group as a whole produces better than one would expect from the average of 38.3 parts per million of active phosphoric acid, but the group averages higher in nitrogen and in total phosphoric acid than the preceding group. Two soils contain 20 parts per million of active phosphoric acid. One of these soils is high in total phosphoric acid, and the other low. One is high in lime, and the other low. The high percentage of nitrogen and total phosphoric acid with the active phosphoric acid account for the better behavior of the first. The second contains nearly as much phosphoric acid extracted by the five extractions as the first, but in other respects the analysis shows no reason why this soil should do so much better than one would expect from the active phosphoric acid. Four soils contain from 32 to 38 parts per million of active phosphoric acid, and three of these soils are high in nitrogen. One soil contains 17.6 per million of active phosphoric acid, but is high in nitrogen and total phosphoric acid.

Soil 5953 gives up the most phosphoric acid of any of the soils here reported, and is very rich in nitrogen and in total phosphoric acid. It is also a limestone soil.

From the foregoing discussion, it appears that a high content of total phosphoric acid, and of total nitrogen is associated with a higher availability of the active, and such soils may give up more phosphoric acid to the roots of plants than soils containing the same content of active phosphoric acid, but much lower in total phosphoric acid or nitrogen. Soils rich in lime are variable, and sometimes give up less phosphoric acid than one would expect, while in other cases they give up more. Sometimes the lime appears to be more favorable, and other times less favorable. The difference may depend upon whether the phosphoric acid taken up by the solvent is exposed to the action of the roots of plants, or protected by the lime. It would appear that limestone soils may contain considerable amounts of phosphoric acid in the form of phosphate of lime which is inclosed within the carbonate of lime, and not dissolved until all the lime is neutralized. This fact causes difficulty in interpreting the results of the analysis. A high nitrogen or a high total phosphoric acid may give better results than usual, but a lime content of one per cent. carbonate or over may neutralize them.

It should be observed that different soils which contain equal amounts of active phosphoric acid, may vary in the chemical nature of the phosphates and their availability for the use of plants.

Table 28.—Pot experiments.—Details.

		Crop in grams		Phosphoric acid	
		KN	KPN	Per cent	Grams
	Series 4				
968	Corn, 1912	1.8	35.0	.21	.0038
	Sorghum, 1912	2.4	12.2	.20	.0048
	Corn, 1913	8.1	42.8	.35	.0284
	Sorghum, 1913	11.2	17.2	.20	.0224
	Total	23.5	107.2	.....	.0594
	Corn, 1914	10.7	37.9	.22	.0235
	Sorghum, 1914	23.3	28.8	.25	.0333
2343	Corn, 1912	4.2	35.1	.19	.0080
	Sorghum, 1912	6.2	20.4	.18	.0112
	Corn, 1913	5.2	34.2	.19	.0099
	Sorghum, 1913	1.1	16.8	.18	.0020
	Total	16.7	106.5	.....	.0311
	Corn, 1914	1.5	34.2	.18	.0027
	Sorghum, 1914	.5	20.7	.....	.....
1135	Corn, 1912	4.8	55.7	.20	.0096
	Sorghum, 1912	6.7	17.8	.19	.0134
	Corn, 1913	8.2	38.5	.21	.0172
	Sorghum, 1913	3.8	14.1	.17	.0065
	Total	23.5	126.5	.....	.0467
	Corn, 1914	2.1	27.7	.23	.0048
	Sorghum, 1914	0	8.4	.....	0
992	Corn, 1912	6.7	32.8	.29	.0194
	Sorghum, 1912	9.9	20.1	.21	.0208
	Corn, 1913	13.0	29.1	.25	.0325
	Sorghum, 1913	5.6	16.9	.15	.0084
	Total	35.2	98.9	.....	.0811
	Corn, 1914	3.5	21.8	.27	.0094
	Sorghum, 1914	3.5	19.2	.24	.0084
1137	Corn, 1912	9.8	58.1	.26	.0255
	Sorghum, 1912	16.1	23.8	.20	.0322
	Corn, 1913	19.4	50.4	.15	.0290
	Sorghum, 1913	5.0	16.4	.22	.0110
	Total	50.3	148.7	.....	.0977

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams		Phosphoric acid	
		KN	KPN	Per cent	Grams
	Corn, 1914	7.0	44.5	.18	.0126
	Sorghum, 1914	3.4	15.0	.22	.0075
937	Corn, 1912	11.2	57.5	.20	.0224
	Sorghum, 1912	16.2	29.7	.15	.0243
	Corn, 1913	12.4	44.3	.19	.0236
	Sorghum, 1913	1.4	7.9	.17	.0024
	Total	41.2	139.4	.....	.0737
	Corn, 1914	3.1	41.1	.24	.0074
	Sorghum, 1914	1.0	0	.22	.0022
913	Corn, 1912	14.8	53.9	.25	.0370
	Sorghum, 1912	14.9	21.4	.18	.0228
	Corn, 1913	14.3	32.9	.18	.0257
	Sorghum, 1913	1.9	6.2	.20	.0038
	Total	45.9	114.4	.....	.0899
	Corn, 1914	2.2	36.7	0.19	.0042
	Sorghum, 1914	0	0.2	0	.0000
2944	Corn, 1912	17.6	58.1	.23	.0405
	Sorghum, 1912	17.0	24.7	.17	.0289
	Corn, 1913	20.2	45.2	.18	.0364
	Sorghum, 1913	6.6	25.2	.21	.0139
	Total	62.0	153.2	.....	.1197
	Corn, 1914	10.1	37.5	.18	.0180
	Sorghum, 1914	7.5	30.7	.23	.0173
895	Corn, 1912	28.3	58.8	.22	.0623
	Sorghum, 1912	15.0	19.3	.18	.0270
	Corn, 1913	18.0	42.8	.18	.0324
	Sorghum, 1913	7.7	13.1	.19	.0146
	Total	69.0	134.0	.....	.1363
	Corn, 1914	7.7	32.9	.17	.131
	Sorghum, 1914	4.5	21.7	.27	.0122
	Series 13				
335	Corn, 1913	2.9	3.9	.34	.0099
	Sorghum, 1913	2.1	12.0	.25	.0025
	Corn, 1914	9.4	40.7	.18	.0169
	Sorghum, 1914	4.4	23.7	.24	.0106
	Total	15.9	76.4	.....	.0399
6681	Corn, 1913	2.2	30.8	.25	.0055
	Sorghum, 1913	1.1	18.9	.21	.0023
	Corn, 1914	5.7	49.5	.14	.0080
	Sorghum, 1914	2.8	28.1	.17	.0048
	Total	11.8	127.3	.....	.0206
3378	Corn, 1913	2.9	16.4	.33	.0096
	Sorghum, 1913	3.7	16.9	.17	.0063
	Corn, 1914	7.5	52.4	.14	.0105
	Sorghum, 1914	2.1	32.4	.19	.0040
	Total	16.2	118.1	.....	.0304
4234	Corn, 1913	3.5	15.7	.27	.0095
	Sorghum, 1913	4.6	16.2	.16	.0074
	Corn, 1914	4.5	30.1	.19	.0086
	Sorghum, 1914	0.9	14.5	.23	.0021
	Total	13.5	76.5	.....	.0276
4596	Corn, 1913	5.0	12.2	.29	.0145
	Sorghum, 1913	7.5	20.9	.18	.0135
	Corn, 1914	4.4	35.4	.15	.0066
	Sorghum, 1914	1.0	15.7	.16	.0016
	Total	17.9	84.2	.....	.0362
3362	Corn, 1913	5.6	30.5	.26	.0146
	Sorghum, 1913	4.9	23.0	.15	.0074
	Corn, 1914	5.1	43.2	.15	.0077
	Sorghum, 1914	1.5	31.0	.17	.0025
	Total	17.1	127.7	.....	.0322

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
3611	Corn, 1913	6.5	22.5	.36	.0234
	Sorghum, 1913	4.7	13.9	.21	.0099
	Corn, 1914	6.9	39.9	.15	.0104
	Sorghum, 1914	0	7.7	.....	.....
	Total	18.1	84.0	.....	.0437
2350	Corn, 1913	8.4	40.2	.27	.0227
	Sorghum, 1913	10.0	31.4	.13	.0130
	Corn, 1914	8.7	47.0	.12	.0102
	Sorghum, 1914	2.5	30.3	.25	.0055
	Total	29.6	148.9	.....	.0514
5969	Corn, 1913	9.6	35.5	.29	.0278
	Sorghum, 1913	10.0	24.7	.15	.0150
	Corn, 1914	12.0	34.0	.13	.0156
	Sorghum, 1914	5.0	25.5	.15	.0075
	Total	37.2	137.7	.....	.0659
5944	Corn, 1913	15.8	26.6	.23	.0363
	Sorghum, 1913	14.7	17.7	.19	.0279
	Corn, 1914	20.4	50.2	.14	.0262
	Sorghum, 1914	9.1	23.5	.18	.0164
	Total	60.0	118.0	.....	.1068
5710	Corn, 1913	19.3	40.4	.29	.0560
	Sorghum, 1913	15.9	11.0	.18	.0286
	Corn, 1914	18.7	59.0	.14	.0262
	Sorghum, 1914	13.0	39.4	.22	.0286
	Total	66.9	149.8	.....	.1394
	Series 14				
3400	Corn, 1913	6.9	34.9	.21	.0145
	Sorghum, 1913	9.0	24.2	.16	.0144
	Corn, 1914	6.2	36.6	.29	.0180
	Sorghum, 1914	5.0	28.0	.36	.0180
	Total	27.1	123.7	.....	.0649
4187	Corn, 1913	9.6	20.0	.26	.0250
	Sorghum, 1913	4.9	4.4	.32	.0157
	Corn, 1914	3.1	18.5	.26	.0081
	Sorghum, 1914	12.0	20.5	.17	.0204
	Total	29.6	63.4	.....	.0692
5967	Corn, 1913	11.5	15.3	.18	.0181
	Sorghum, 1913	8.7	23.1	.19	.0165
	Corn, 1914	7.5	31.9	.24	.0180
	Sorghum, 1914	11.4	28.6	.24	.0274
	Total	39.1	98.9	.....	.0800
4186	Corn, 1913	12.6	15.7	.31	.0391
	Sorghum, 1913	13.2	12.9	.33	.0436
	Corn, 1914	19.0	36.0	.22	.0418
	Sorghum, 1914	27.7	37.0	.24	.0665
	Total	72.5	101.6	.....	.1910
6884	Corn, 1913	15.2	53.6	.15	.0228
	Sorghum, 1913	7.2	24.8	.18	.0130
	Corn, 1914	6.0	41.9	.19	.0114
	Sorghum, 1914	6.0	29.5	.23	.0138
	Total	34.4	149.8	.....	.0610
6680	Corn, 1913	15.7	56.4	.19	.0298
	Sorghum, 1913	17.1	29.0	.19	.0325
	Corn, 1914	11.2	50.3	.15	.0168
	Sorghum, 1914	13.0	42.0	.22	.0286
	Total	57.0	177.7	.....	.1077

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
3333	Corn, 1913	32.8	41.0	.18	.0590
	Sorghum, 1913	18.0	23.5	.21	.0378
	Corn, 1914	19.2	40.7	.17	.0326
	Sorghum, 1914	21.9	32.6	.22	.0472
	Total	91.9	137.8	.....	.1766
894	Corn, 1913	34.6	49.9	.17	.0588
	Sorghum, 1913	16.8	17.4	.28	.0470
	Corn, 1914	15.9	43.7	.18	.0286
	Sorghum, 1914	8.0	22.8	.28	.0224
	Total	75.3	133.8	.....	.1568
	Series 17				
5100	Corn, 1913	48.7	51.4	.21	.1023
	Sorghum, 1913	30.2	31.7	.18	.0544
	Corn, 1914	31.8	48.9	.14	.0445
	Sorghum, 1914	9.7	17.4	.20	.0194
	Total	120.4	149.4	.....	.2206
4291	Corn, 1913	13.0	15.1	.20	.0260
	Sorghum, 1913	6.5	1.2	.29	.0189
	Corn, 1914	14.0	29.0	.12	.0168
	Sorghum, 1914	3.9	0.5	.32	.0125
	Total	37.4	45.8	.....	.0742
2353	Corn, 1913	15.4	51.7	.23	.0354
	Sorghum, 1913	28.7	33.7	.18	.0517
	Corn, 1914	36.9	49.2	.10	.0369
	Sorghum, 1914	11.2	15.7	.15	.0168
	Total	92.2	150.3	.....	.1408
936	Corn, 1613	32.1	44.7	.21	.0674
	Sorghum, 1913	13.4	15.7	.28	.0375
	Corn, 1914	30.7	46.9	.12	.0367
	Sorghum, 1914	8.4	16.9	.22	.0185
	Total	84.6	124.2	.....	.1601
5945	Corn, 1913	35.9	49.4	.20	.0718
	Sorghum, 1913	14.0	16.0	.22	.0308
	Corn, 1914	27.5	47.2	.14	.0385
	Sorghum, 1914	17.4	18.5	.13	.0325
	Total	94.8	131.1	.....	.1736
5943	Corn, 1913	45.4	50.7	.23	.1044
	Sorghum, 1913	21.1	23.9	.25	.0528
	Corn, 1914	36.7	47.7	.13	.0477
	Sorghum, 1914	19.4	27.7	.18	.0349
	Total	122.6	150.0	.....	.2398
	Series 27				
970	Corn, 1914	5.0	19.0	.41	.0205
	Sorghum, 1914	12.4	36.3	.23	.0285
	Corn, 1915	28.0	39.5	.16	.0448
	Sorghum, 1915	23.4	32.2	.18	.0421
	Total	68.8	127.0	.....	.1359
7240	Corn, 1914	12.6	38.7	.33	.0416
	Sorghum, 1914	11.5	24.4	.24	.0276
	Corn, 1915	18.4	35.1	.22	.0405
	Sorghum, 1915	6.5	7.7	.25	.0162
	Total	49.0	105.9	.....	.1259
6882	Corn, 1914	12.7	19.2	.24	.0305
	Sorghum, 1914	18.2	24.2	.18	.0328
	Corn, 1915	11.2	28.0	.20	.0224
	Sorghum, 1915	10.1	29.5	.20	.0202
	Total	52.2	100.9	.....	.1059

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
7252	Corn, 1914	22.5	26.1	.34	.0765
	Sorghum, 1914	2.8	21.0	.44	.0123
	Corn, 1915	11.8	29.3	.19	.0224
	Sorghum, 1915	0	dead	0	0
	Total	37.1	76.4	.....	.1112
7107	Corn, 1914	23.2	19.6	.36	.0858
	Sorghum, 1914	22.0	21.0	.44	.0123
	Corn, 1915	22.6	31.5	.19	.0429
	Sorghum, 1915	19.7	24.6	.27	.0532
	Total	198.7	96.7	.....	.1942
7169	Corn, 1914	24.3	39.2	.25	.0608
	Sorghum, 1914	23.9	30.5	.22	.0526
	Corn, 1915	11.1	36.9	.20	.0222
	Sorghum, 1915	6.0	15.5	.25	.0150
	Total	65.3	122.1	.....	.1506
6883	Corn, 1914	24.5	32.9	.27	.0462
	Sorghum, 1914	33.0	32.0	.17	.0561
	Corn, 1915	15.7	39.9	.21	.0330
	Sorghum, 1915	10.5	24.7	.18	.0189
	Total	83.7	12.95	.....	.1542
7159	Corn, 1914	28.5	36.0	.28	.0798
	Sorghum, 1914	26.6	28.5	.21	.0559
	Corn, 1915	21.4	41.5	.17	.0364
	Sorghum, 1915	9.6	18.0	.20	.0192
	Total	86.1	124.0	.....	.1913
7225	Corn, 1914	29.4	33.0	.32	.0928
	Sorghum, 1914	29.9	33.7	.29	.0867
	Corn, 1915	25.0	30.5	.19	.0338
	Sorghum, 1915	3.2	3.3	.34	.0108
	Total	87.5	100.5	.....	.2241
7265	Corn, 1914	38.5	45.5	.17	.0655
	Sorghum, 1914	21.5	26.5	.23	.0495
	Corn, 1915	17.8	38.5	.19	.0338
	Sorghum, 1915	0.2	5.5	.17	.0003
	Total	78.0	116.0	.....	.1491
	Series 28				
5954	Corn, 1914	13.7	24.7	.27	.0370
	Sorghum, 1914	19.6	24.5	.26	.0510
	Corn, 1915	22.7	36.8	.17	.0386
	Sorghum, 1915	17.1	26.2	.18	.0308
	Total	73.1	112.2	.....	.1574
7241	Corn, 1914	23.7	30.7	.20	.0474
	Sorghum, 1914	16.2	26.9	.24	.0389
	Corn, 1915	11.8	35.0	.19	.0224
	Sorghum, 1915	12.7	24.2	.20	.0254
	Total	64.4	116.8	.....	.1341
6976	Corn, 1914	24.7	40.7	.27	.0687
	Sorghum, 1914	22.5	26.0	.22	.0495
	Corn, 1915	15.6	48.9	.14	.0218
	Sorghum, 1915	11.7	36.2	.17	.0199
	Total	74.5	151.8	.....	.1599
5958	Corn, 1914	27.2	36.4	.25	.0680
	Sorghum, 1914	28.4	33.5	.24	.0682
	Corn, 1915	25.9	41.0	.16	.0414
	Sorghum, 1915	17.2	34.2	.17	.0292
	Total	98.7	145.1	.....	.2068

Table 28.—Pot Experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
5966	Corn, 1914	32.9	30.5	.27	.0888
	Sorghum, 1914	30.5	35.0	.28	.0854
	Corn, 1915	29.8	37.7	.19	.0526
	Sorghum, 1915	22.3	29.2	.18	.0401
	Total	115.5	132.4	.....	.2669
7227	Corn, 1914	41.0	46.0	.38	.1573
	Sorghum, 1914	29.9	32.2	.18	.0539
	Corn, 1915	16.6	39.3	.14	.0232
	Sorghum, 1915	12.0	19.0	.17	.0208
	Total	99.5	136.5	.....	.2552
5953	Corn, 1913	41.4	46.4	.38	.1573
	Sorghum, 1913	33.4	34.2	.42	.1403
	Corn, 1915	43.2	51.3	.27	.1166
	Sorghum, 1915	35.2	39.0	.34	.1197
	Total	153.2	170.9	.....	.5339
5957	Corn, 1914	43.5	40.7	.30	.1305
	Sorghum, 1914	29.2	29.0	.32	.0934
	Corn, 1915	42.4	42.9	.19	.0706
	Sorghum, 1915	36.2	28.2	.26	.0941
	Total	151.3	140.8	.....	.3886
	Series 29				
7245	Corn, 1914	5.2	30.9	.19	.0099
	Sorghum, 1914	5.0	31.5	.21	.0105
	Corn, 1915	6.0	32.4	.18	.0128
	Sorghum, 1915	1.5	7.5	.22	.0033
	Total	17.7	102.3	.....	.0365
7255	Corn, 1914	7.6	34.9	.21	.0160
	Sorghum, 1914	6.2	29.1	.23	.0143
	Corn, 1915	3.0	31.7	.22	.0066
	Sorghum, 1915	1.6	15.5	.25	.0025
	Total	18.4	111.2	.....	.0394
7121	Corn, 1914	7.9	27.8	.18	.0142
	Sorghum, 1914	8.4	36.2	.22	.0185
	Corn, 1915	7.4	38.9	.17	.0126
	Sorghum, 1915	3.4	21.4	.15	.0051
	Total	27.1	124.3	.....	.0504
7238	Corn, 1914	9.7	26.8	.19	.0184
	Sorghum, 1914	10.2	27.5	.21	.0214
	Corn, 1915	7.9	36.2	.16	.0126
	Sorghum, 1915	4.0	18.5	.20	.0080
	Total	31.8	109.0	.....	.0604
7242	Corn, 1914	10.5	35.5	.19	.0200
	Sorghum, 1914	10.0	22.0	.17	.0170
	Corn, 1915	5.8	30.2	.15	.0087
	Sorghum, 1915	0.5	.....	.29	.0014
	Total	26.8	87.7	.....	.0471
7120	Corn, 1914	11.5	39.7	.17	.0196
	Sorghum, 1914	16.6	33.3	.22	.0365
	Corn, 1915	8.8	39.4	.16	.0141
	Sorghum, 1915	3.8	22.7	.17	.0065
	Total	40.7	112.4	.....	.0767
7251	Corn, 1914	13.3	38.7	.18	.0239
	Sorghum, 1914	13.5	32.5	.19	.0257
	Corn, 1915	7.3	38.0	.16	.0137
	Sorghum, 1915	3.5	13.5	.15	.0053
	Total	37.6	122.7	.....	.0686

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
	Series 30				
7266	Corn, 1914	5.0	8.4	.55	.0275
	Sorghum, 1914	2.1	3.4	.37	.0078
	Corn, 1915	9.7	20.1	.43	.0417
	Sorghum, 1915	10.7	8.5	.28	.0290
	Total	27.5	40.4	.....	.1060
7234	Corn, 1914	5.7	32.7	.32	.0182
	Sorghum, 1914	3.0	18.8	.35	.0105
	Corn, 1915	4.8	19.3	.17	.0082
	Sorghum, 1915	0	0	.....	.....
	Total	13.5	71.8	.....	.0369
5956	Corn, 1914	9.0	21.4	.28	.0252
	Sorghum, 1914	16.9	28.8	.26	.0429
	Corn, 1915	15.0	41.3	.19	.0285
	Sorghum, 1915	12.2	24.4	.15	.0183
	Total	53.1	115.9	.....	.0966
7154	Corn, 1914	9.5	38.7	.19	.0181
	Sorghum, 1914	6.6	24.0	.24	.0158
	Corn, 1915	3.9	31.4	.19	.0074
	Sorghum, 1915	.....	3.5	.....	.....
	Total	20.0	97.6	.....	.6413
4650	Corn, 1914	10.0	16.4	.19	.0190
	Sorghum, 1914	0	20.8	.....	.....
	Corn, 1915	9.1	28.2	.16	.0146
	Sorghum, 1915	2.7	13.7	.19	.0051
	Total	21.8	79.1	.....	.0387
2828	Corn, 1914	11.9	22.6	.29	.0345
	Sorghum, 1914	21.5	0	.23	.0495
	Corn, 1915	24.3	54.3	.20	.0486
	Sorghum, 1915	18.9	22.5	.23	.0434
	Total	76.6	99.4	.....	.1760
7224	Corn, 1914	12.0	11.5	.25	.0300
	Sorghum, 1914	15.2	20.7	.25	.0380
	Corn, 1915	12.4	28.4	.16	.0198
	Sorghum, 1915	10.2	24.2	.14	.0143
	Total	49.8	84.8	.....	.1021
7162	Corn, 1914	12.2	36.5	.23	.0281
	Sorghum, 1914	12.3	24.0	.24	.0295
	Corn, 1915	11.7	30.9	.19	.0223
	Sorghum, 1915	6.0	13.4	.22	.0132
	Total	42.2	104.8	.....	.0931
7150	Corn, 1914	14.2	34.9	.18	.0256
	Sorghum, 1914	6.5	16.8	.23	.0150
	Corn, 1915	4.1	12.7	.19	.0078
	Sorghum, 1915	0	.....	.....	.....
	Total	24.8	64.4	.....	.0484
7181	Corn, 1914	15.9	30.2	.23	.0366
	Sorghum, 1914	11.2	17.2	.20	.0224
	Corn, 1915	8.1	26.7	.25	.0203
	Sorghum, 1915	8.2	18.2	.17	.0139
	Total	91.8	92.3	.....	.0932
1200	Corn, 1914	16.0	25.0	.24	.0384
	Sorghum, 1914	0.2	0	.22	.0004
	Corn, 1915	8.0	39.7	.25	.0200
	Sorghum, 1915	0	.....	.....	.....
	Total	24.2	64.7	.....	.0588

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
7233	Corn, 1914	17.6	29.8	.23	.0405
	Sorghum, 1914	2.3	7.7	.65	.0150
	Corn, 1915	12.5	27.0	.21	.0262
	Sorghum, 1915	0.2	17.7	.18	.0004
	Total	32.6	82.2	.....	.0821
7228	Corn, 1914	18.0	29.0	.30	.0540
	Sorghum, 1914	18.4	23.6	.20	.0368
	Corn, 1915	9.1	25.3	.19	.0172
	Sorghum, 1915	6.0	11.7	.19	.0114
	Total	51.5	89.6	.....	.1194
7118	Corn, 1914	22.6	38.0	.22	.0497
	Sorghum, 1914	19.8	18.0	.24	.0475
	Corn, 1915	8.3	27.0	.23	.0191
	Sorghum, 1915	9.9	14.7	.19	.0188
	Total	60.5	97.7	.....	.1351
7254	Corn, 1914	22.7	38.7	.18	.0409
	Sorghum, 1914	6.5	9.4	.29	.0189
	Corn, 1915	12.4	52.4	.17	.0211
	Sorghum, 1915	0.5	7.1	.18	.0009
	Total	42.1	107.7	.....	.0818
7145	Corn, 1914	24.7	30.7	.23	.0568
	Sorghum, 1914	20.1	19.0	.28	.0563
	Corn, 1915	12.6	37.7	.17	.0214
	Sorghum, 1915	9.7	15.5	.15	.0146
	Total	67.1	102.9	.....	.1491
7237	Corn, 1914	24.7	41.7	.20	.0494
	Sorghum, 1914	19.8	30.2	.16	.0317
	Corn, 1915	16.0	47.1	.15	.0240
	Sorghum, 1915	5.7	15.2	.21	.0120
	Total	66.2	134.2	.....	.1171
7244	Corn, 1914	25.2	42.7	.21	.0529
	Sorghum, 1914	8.9	17.3	.34	.0303
	Corn, 1915	8.0	37.5	.19	.0163
	Sorghum, 1915	1.0	12.0	.30	.0030
	Total	43.1	109.5	.....	.1025
	Series 36				
9187	Corn, 1915	7.2	37.1	.30	.0212
	Sorghum, 1915	11.5	26.4	.17	.0195
	Corn, 1916	6.8	29.9	.17	.0115
	Sorghum, 1916	3.9	42.2	.14	.0055
	Total	29.4	135.6	.....	.0577
7346	Corn, 1915	15.1	36.1	.30	.0453
	Sorghum, 1915	13.5	18.5	.24	.0324
	Corn, 1916	5.7	20.9	.23	.0131
	Sorghum, 1916	10.0	25.5	.16	.0155
	Total	94.3	101.0	.....	.1063
7708	Corn, 1915	15.6	21.5	.30	.0468
	Sorghum, 1915	16.7	25.5	.23	.0384
	Corn, 1916	20.9	22.9	.17	.0355
	Sorghum, 1916	22.4	36.7	.15	.0336
	Total	75.6	106.6	.....	.1543
7341	Corn, 1915	18.4	27.4	.38	.0699
	Sorghum, 1915	21.0	18.0	.20	.0420
	Corn, 1916	11.4	23.0	.18	.0205
	Sorghum, 1916	20.4	10.5	.135	.0275
	Total	71.2	78.9	.....	.1599

Table 28—Continued.—Pot experiments.—Details.

		Crop in grams.		Phosphoric acid.	
		KN	KDN	Per cent	Grams
9333	Corn, 1915	20.1	41.7	.25	.0503
	Sorghum, 1915	10.0	21.5	.21	.0210
	Corn, 1916	7.7	37.9	.24	.0184
	Sorghum, 1916	9.4	33.2	.12	.0113
	Total	47.2	134.3	.....	.1010
9311	Corn, 1915	20.6	35.4	.22	.0543
	Sorghum, 1915	14.0	21.4	.17	.0238
	Corn, 1916	9.2	38.0	.20	.0184
	Sorghum, 1916	10.1	36.3	.14	.0141
	Total	53.9	131.1	.....	.1106
7374	Corn, 1915	22.5	28.3	.21	.0473
	Sorghum, 1915	14.9	26.2	.15	.0223
	Corn, 1916	11.6	35.0	.19	.0220
	Sorghum, 1916	14.4	37.8	.145	.0209
	Total	63.4	127.3	.....	.1125
9305	Corn, 1915	22.7	41.7	.23	.0522
	Sorghum, 1915	13.0	13.6	.17	.0238
	Corn, 1916	6.4	37.2	.23	.0147
	Sorghum, 1916	11.9	36.0	.13	.0155
	Total	54.0	128.5	.....	.1062
9378	Corn, 1915	28.5	39.5	.23	.0656
	Sorghum, 1915	12.7	26.0	.20	.0254
	Corn, 1916	12.7	34.5	.18	.0228
	Sorghum, 1916	10.2	37.7	.11	.0112
	Total	64.1	137.7	.....	.1250

Table 28—Continued.—Pot experiments.—Details.

Series 47		Crop in grams		Phosphoric acid		Phosphoric acid		
		KN	KDN	Per cent	Grams	KNCA	Per cent	Grams
9314	Corn, 1916	3.4	13.5	.27	.0091	1.9	.27	.0051
	Sorghum, 1916	9.0	26.9	.15	.0135	8.5	.17	.0144
	Corn, 1917	4.5	24.7	.30	.0135	4.0	.24	.0096
	Sorghum, 1917	3.6	21.1	.17	.0061	4.1	.17	.0070
	Total	20.5	86.2	.....	.0422	18.5	.....	.0361
9164	Corn, 1916	4.4	29.8	.28	.0123	2.2	.33	.0072
	Sorghum, 1916	0.9	14.2	.41	.0037	4.4	.235	.0103
	Corn, 1917	1.7	17.9	.29	.0049	3.1	.23	.0072
	Sorghum, 1917	.....	8.2	.....	.....	1.6	.23	.0037
	Total	7.0	70.1	.....	.0209	11.3	.....	.0283
9285	Corn, 1916	7.5	35.5	.20	.0150	5.0	.22	.0110
	Sorghum, 1916	3.5	5.9	.27	.0093	7.2	.25	.0180
	Corn, 1917	2.5	28.5	.20	.0050	5.0	.26	.0130
	Sorghum, 1917	1.0	19.4	.25	.0025	4.7	.21	.0098
	Total	14.5	89.3	.....	.0318	21.9	.....	.0518
9168	Corn, 1916	8.9	23.9	.22	.0195	9.2	.23	.0211
	Sorghum, 1916	9.6	25.7	.23	.0221	11.3	.19	.0215
	Corn, 1917	7.0	29.8	.23	.0161	5.8	.22	.0128
	Sorghum, 1917	7.6	18.2	.16	.0122	5.9	.22	.0130
	Total	33.1	97.6	.....	.0699	32.2	.....	.0684
9183	Corn, 1916	11.0	38.5	.22	.0242	10.5	.24	.0252
	Sorghum, 1916	12.5	29.0	.24	.0300	6.8	.235	.0160
	Corn, 1917	7.0	27.0	.26	.0182	5.8	.28	.0162
	Sorghum, 1917	8.8	21.4	.17	.0150	9.0	.19	.0171
	Total	39.3	115.9	.....	.0874	32.1	.....	.0745

Table 28—Continued.—Pot experiments.—Details.

	Series 47	Crop in grams		Phosphoric acid		Phosphoric acid		
		KN	KDN	Per cent	Grams	KNCA	Per cent	Grams
9353	Corn, 1916	12.7	52.7	.17	.0215	13.5	.19	.0256
	Sorghum, 1916	11.4	43.2	.145	.0165	12.4	.13	.0161
	Corn, 1917	6.0	31.8	.26	.0156	7.7	.25	.0193
	Sorghum, 1917	3.0	15.5	.20	.0062	9.9	.17	.0168
	Total	33.1	143.2	.....	.0598	43.5	.....	.0778
9331	Corn, 1916	15.7	31.6	.21	.0329	13.2	.21	.0277
	Sorghum, 1916	2.8	18.7	.205	.0056	8.9	.175	.0156
	Corn, 1917	3.5	18.2	.29	.0101	7.0	.25	.0175
	Sorghum, 1917	6.1	6.4	.21	.0128	5.1	.22	.0112
	Total	28.1	74.9	.....	.0614	34.2	.....	.0720
9279	Corn, 1916	19.5	45.3	.17	.0331	15.7	.17	.0266
	Sorghum, 1916	12.7	26.7	.15	.0191	11.7	.183	.0215
	Corn, 1917	7.1	28.0	.18	.0128	6.0	.21	.0126
	Sorghum, 1917	2.9	21.7	.22	.0064	5.8	.25	.0245
	Total	42.2	121.7	.....	.0714	39.2	.....	.0852
9277	Corn, 1916	24.2	36.2	.16	.0387	20.0	.19	.0380
	Sorghum, 1916	11.7	5.4	.195	.0228	11.9	.16	.0190
	Corn, 1917	6.0	22.5	.22	.0132	6.9	.23	.0159
	Sorghum, 1917	3.6	13.8	.18	.0064	5.6	.18	.0100
	Total	45.5	77.9	.....	.0811	44.4	.....	.0829

SUMMARY AND CONCLUSIONS.

This bulletin discusses the relation between the chemical composition and the results of pot experiments with ninety-five samples of soil.

The total weights of four crops, grown during two years, on soils which received potash and nitrogen, but no phosphoric acid, on an average, increase with the active phosphoric acid of the soil, with the exception of one series. The same conclusion is reached whether one considers the first crop alone or the first and second crops combined, or the first three crops combined, or the fourth crop alone, or all four crops combined, or phosphoric acid removed by the various crops.

There is a variation in the amount of phosphoric acid removed or the size of the crop, grown on different soils containing the same amounts of active phosphoric acid. The chief object of the present work is to ascertain the causes of these differences.

The total phosphoric acid, ignition-soluble phosphoric acid, phosphoric acid soluble in cold 10 per cent. hydrochloric acid, active phosphoric acid dissolved by five successive extractions, active potash, lime, acidity, surface or subsoil, and acid consumed, were taken into consideration.

When the soils of the same active phosphoric acid content were divided into groups of high, average, and low crop production, while the average relation to the analysis is irregular, there is a tendency for soils containing a total phosphoric acid, or a total nitrogen higher than the average, to give higher yields of phosphoric acid to crops than soils with the same quantities of active phosphoric acid, but containing the average amounts of total phosphoric acid and nitrogen.

Surface soils containing the same amounts of active phosphoric acid, will, on an average, give up more phosphoric acid to crops than subsoils containing corresponding amounts of active phosphoric acid. This relation does not hold in all cases.

There is some tendency for soils containing the same amounts of active phosphoric acid to give up more phosphoric acid to crops as the total phosphoric acid increases, but this difference is not clearly marked.

There seems to be a slight tendency for soils which contain equal amounts of active phosphoric acid to give up more phosphoric acid to crops if they contain more nitrogen, which usually means that they contain more organic matter.

Soils with the same content of active phosphoric acid, and which are not acid, on an average, give up more phosphoric acid, and produce larger crops, than those which are acid. This relation does not hold in all cases.

No relations could be observed when soils containing the same amounts of active phosphoric acid were arranged in groups according to the acid consumed, which indicates the amount of bases present.

When the soils are arranged in groups according to the phosphoric acid withdrawn by the crops in the pot experiments, there is a better relation between the active phosphoric acid and the crop production than any other character. The total phosphoric acid is lowest for the first group and highest for the last group, but groups 2, 3, 4, and 5 contain nearly the same quantities of total phosphoric acid. The nitrogen increases regularly from the first group to the sixth group, with the exception of group 5. The phosphoric acid dissolved after ignition, increases with the first three groups, and is highest with the sixth group, but is irrerular with groups 4 and 5.

Statistical methods show that there is a better relation between the active phosphoric acid and the phosphoric acid removed by four crops, than between the total phosphoric acid in the soil and the phosphoric acid removed by four crops. The correlation coefficient for the active phosphoric acid is .57 and for the total phosphoric acid .45.

There does not seem to be any relation between the active phosphoric acid extracted by five extractions, and the relative production in the groups arranged according to the active phosphoric acid taken from the soil by crops.

Correction of the acid for acid neutralized by the soil, when all the acid is neutralized, would throw the analyses out of relation with the pot experiments.

The presence of lime renders the interpretation of the analyses more difficult, as it may act in two entirely different ways. Sometimes it is accompanied by a higher utilization of the phosphoric acid, and sometimes by a lower utilization, in soils of corresponding active phosphoric acid content.