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A. B. CONNER, DIRECTOR
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DIVISION OF CHEMISTRY

Availability of the Phosphoric Acid of Finely-Divided Rock Phosphate

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**In cooperation with U. S. Department of Agriculture.
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Soft phosphate with colloidal clay and finely ground rock phosphate both contain phosphoric acid which has a much lower availability to plants than the phosphoric acid of superphosphate, especially on neutral or basic soils such as generally prevail in Texas.

The soft phosphate with colloidal clay is a finely-divided phosphate of natural occurrence, which is a by-product from mining rock phosphate in Florida. The finely ground rock phosphate was from Tennessee rock.

The availability of the phosphoric acid in soft phosphate with colloidal clay in 7 pot experiments was found to vary from 0 to 120 with an average of 40 compared with the phosphoric acid of superphosphate as 100. The availability was low on the slightly basic soils, high on one acid soil, but about the average on some of the other acid soils.

In 5 pot experiments the availability of the phosphoric acid of finely-ground rock phosphate was only 40 per cent of that of superphosphate. Its availability seemed to be lower on neutral or basic soils than on acid soils.

On some acid soils, the availability of the phosphoric acid of both soft phosphate with colloidal clay and finely ground rock phosphate is equal to that of superphosphate, but on other acid soils the availability is decidedly less than that of superphosphate.

CONTENTS

AVAILABILITY OF THE PHOSPHORIC ACID OF FINELY-DIVIDED ROCK PHOSPHATE

G. S. Fraps

About a hundred years ago, it was discovered that when ground bones were treated with acids such as sulphuric acid, the treated bones had a much greater effect upon plant growth than the untreated bones. A little later it was found that naturally-occurring rock phosphate when ground and treated with acids likewise had a much greater effect upon plant growth than the raw rock phosphate. The acid acted upon the bones or phosphate rock in such a way as to permit the plant roots to take up the phosphoric acid. The phosphoric acid was changed to what is termed an available form. Upon this discovery was founded the great fertilizer industry, which now supplies nitrogen and potash as well as phosphoric acid in available forms.

There are some deposits of phosphates which are unsuitable for the manufacture of superphosphate, because they either contain other substances which interfere with the action of the acid or use up too much of it, or because they do not contain enough phosphoric acid to permit of the manufacture of a commercial grade of superphosphate. These phosphates may be used directly for fertilizing purposes, though it is generally recognized that the availability of their phosphoric acid is much lower than that in superphosphate, and that the cost of the fertilizer may not be recovered in the first season the rock phosphate is applied. Some agronomists, notably C. G. Hopkins, have advocated for permanent fertility the use of larger quantities of rock phosphate combined with a legume rotation to secure nitrogen. The value of rock phosphate has been considerably studied and many of the results are summarized by Collings (2).

Claims have been made that phosphate rock which has been very finely ground, or phosphates which are naturally finely divided, contain phosphoric acid in a highly available condition and approach superphosphate in their value (3, 7). The work here reported was planned for the purpose of testing these claims.

Soft Phosphate with Colloidal Clay

This product is defined by the Association of Official Agricultural Chemists (6) as follows:

"A very finely divided low analysis by-product resulting in mining Florida rock phosphate by a hydraulic process whereby the colloidal material settles more abundantly at points in artificial ponds and basins farthest from the washer, where it is later recovered upon the natural evaporation of the water."

Jacob, Hill and Holmes (8) give information regarding this material. They state that the Florida hard rock phosphate deposits usually contain a relatively high percentage of finely-divided phosphatic material classified under the general term, soft phosphate. Soft phosphate also occurs in smaller quantities in the Florida pebble phosphate deposits and to a certain extent as individual deposits in both the hard rock and pebble phosphate districts. Finely divided phosphates also occur in the Tennessee brown rock phosphate field and probably, to a certain extent, in the other phosphate deposits in this country.

Florida soft phosphate (8), usually occurs in the form of more or less soft, white lumps and when wet exhibits the plastic, sticky characteristics of clay. It is variable in composition, but Wyatt reports as an average analysis of 148 samples, 65.15 per cent tricalcium phosphate and 9.2 per cent oxides of iron and alumina.

During the process of preparing Florida hard rock phosphates for the market (8), the soft phosphate present in the matrix is washed into wasteponds where it settles out along with the clay and other impurities, the finer particles concentrating at points farthest from the entrance to the pond. When the ponds become filled with waste material they are allowed to dry up and the water from the phosphate washers is turned into new ponds. These "waste-pond" phosphates, which usually vary in shade from white to a light straw color, are composed of very fine particles and when wet they are quite plastic and sticky. Upon drying they shrink and crack in the manner characteristic of materials containing high percentages of colloid. The air-dried lumps disintegrate rapidly when placed in water. The air-dry material usually contains about 40 to 55 per cent tri-calcium phosphate and about 15 to 18 per cent iron and aluminum oxides. The abandoned waste ponds in the Florida hard rock phosphate district contain several million tons of this material.

Owing to the relatively low content of phosphoric acid and high content of iron and aluminum, it has not been considered practicable to attempt the conversion of soft phosphate into super-phosphate by treatment with sulphuric or other acids (8). Waggaman (9), and Matson, have suggested, however, that owing to the fineness of the particles, it should prove a valuable phosphate fertilizer material for direct application to certain types of soil. A small quantity has been produced annually for this purpose.

Jacob, Hill, and Holmes (8) extracted 60 per cent of colloidal material from the waste-pond phosphates, 38.1 per cent from the soft phosphate, and 11.5 per cent from Tennessee rock phosphate ground to pass a 100-mesh sieve. In the same order the colloidal material contained 18.1, 31.3 and 25.0 per cent of phosphoric acid corresponding to 46.4, 38.1 and 8.5 per cent of the phosphoric acid in the original phosphates.

Sellers of this waste-pond phosphate, or soft phosphate with colloidal clay, have made exaggerated claims with respect to it, some of which are as follows (3):

> "COLLOIDAL PHOSPHATE has COLLOIDAL availability and is the only natural phosphate highly available, having the unique physical property of the colloid. This physical property is as important

as its chemical property. Colloids regulate the plant's feeding ability and determine the soil's productiveness. They attract, hold, and regulate nitrogen, moisture and other elements. They give to the soil greater capillarity. "COLLOIDAL PHOSPHATE is both electrolytic and catalytic. It builds into the plant; resistance, vitality and energy. It restores to soils their virgin qualities. It gives to the soil many of the rare elements essential to plant growth.

"It stimulates and increases the growth of bacteria in the soil. It has high exchange capacity and prevents transference of plant foods in the plant. It contains the elements that are essential in the transposition of starches into carbohydrates, as well as the elements that are essential to the process known as photosynthesis.

"COLLOIDAL PHOSPHATE hastens germination, and brings about early maturity of the crop, enabling it to reach the market earlier. It also gives to the fruit firmness, good texture; improving the color and flavor."

The product referred to may be considered only as a source of phosphoric acid, and the other claims may be disregarded, since there is practically no evidence to support them.

Finely-Ground Rock Phosphate

Finely ground rock phosphate, sometimes sold as Ruhm Phosphate, or "Lime phosphate" is made from Tennessee rock phosphate. The dried phosphate is ground and the fine materials are separated by air currents which, carefully controlled, carry out the fine particles as fast as they are powdered, the coarser particles remaining in the mill until they are ground small enough to float in air.

"Lime Phosphate" as prepared at present (7), has been claimed to contain approximately 80% of particles that will pass through a 400 mesh screen. The old standard, pre-war, was 90% through 100 mesh Lime Phosphate is much finer than Portland Cement, that part passing through 400 mesh is finer than flour."

It is claimed (7) that Experiment Stations which have made comparisons unfavorable to rock phosphate and in favor of acid phosphate have almost without exception compared acidulated phosphate with rock phosphate ground by fertilizer factories, almost as coarsely as Lawes ground it 75 years ago, 99% through a 60 mesh sieve.

It is also claimed (7) that new experiments of many States with "Lime Phosphate" are rapidly showing identical results from both products. We have not found reports of such experiments, though Ames and Kitsuta (1) found that the phosphoric acid of finely ground phosphate rock was more available than the ordinary rock, while not as available as superphosphate.

Previous Work

There is a considerable amount of work which shows that rock phosphate is less available to plants than superphosphate, though the relative availability depends both on the soil and the plant being grown. No attempt will be made here to cite the various reports which have been made regarding rock phosphate, since it is not pertinent to the study here reported. Some are summarized by Collings (2). This Station (4) reported that in pot experiments on an average the availability of the phosphoric acid of rock phosphate is 21 per cent of that of superphosphate, though it varied with different soils.

H. D. Haskins reports (5) the results of a vegetation experiment with soft phosphate with colloidal clay. The results depended somewhat upon the quantity of phosphoric acid used. Compared on the yields of dry matter, with superphosphate as 100, the soft phosphate had an availability of zero when used in small quantity, 22.0 per cent when used in what was termed optimum quantity and 62.5 per cent when used in large quantity. The high result was due partly to a depression in yield of the crop receiving the high amount of superphosphate. Compared with the phosphoric acid of superphosphate as 100, on the basis of the phosphoric acid absorbed by the plant, the availability with the low quantity of phosphate was 26.6, with optimum phosphate 38.4 and with high phosphate 61.5.

Methods for Estimating Availability

There is no chemical method for estimating the availability of rock phosphate or soft phosphate with colloidal clay. The method of the A. O. A. C. for citrate—soluble phosphoric acid is intended only for superphosphates or similar phosphates containing mono-calcium phosphate and di-calcium phosphate and is not intended for rock phosphate of any kind. The method for citric acid soluble phosphoric acid is for use with Thomas or basic slag, which is a by-product from the manufacture of steel. The method is not intended to ascertain the availability of phosphoric acid in any other kind of phosphate.

The only available method of comparing the availability of the phosphoric acid of rock phosphate, soft phosphate with colloidal clay or mineral phosphates in general is by means of pot experiments or field experiments with plants.

Plan of Work

The comparisons of the availability of the phosphoric acid of soft phosphate with colloidal clay and superphosphate were made according to our usual procedure with pot experiments. The soft phosphate contained 20.09 per cent of total phosphoric acid, the Ruhm phosphate No. 33424 contained 33.51 per cent and the superphosphate F 36120 contained 18.45 per cent of available phosphoric acid. To 5000 gms. of soil in galvanized iron pots, 1 gm. ammonium nitrate and 1 gm. potassium sulphate were added. The phosphate addition contained 0.1 gm. phosphoric acid in all soils except No. 31322, which received .08 gm. phosphoric acid. Water equal to one-half the water capacity of the soil was added. Corn was planted, thinned to 3 plants in a pot, watered 3 times a week, harvested, dried, weighed, and the phosphoric acid estimated. The avail-

Table 1. Analysis of soils used in pot experiments

Laboratory number		Nitrogen per cent	Total phos. ac. per cent	Active phos. ac. per million	Total potash per cent	Acid soluble potash per cent	Active potash per million	Acid soluble lime per cent	Basicity per cent	pH	Depth, inches
32647	Lake Charles very fine sandy loam	.065	.020	6	1.03	.21	81	.54	.91	7.60	7-13
31322	Amarillo Silty Clay Loam	.084	.042	54	2.18	—	410	—	1.53	7.89	7-19
33140	Gainer Clay	.039	.036	5	.63	.17	157	.58	1.00	5.28	14-24
33125	Moscow fine sandy loam	.036	.019	8	1.04	.04	60	.11	.12	4.95	3-7
32649	Lake Charles Clay	.168	.034	13	1.21	.36	184	.49	1.32	5.79	0-7
33138	Wilson Clay	.124	.028	9	.62	—	220	—	2.15	5.70	7-14
32650	Lake Charles Clay	.097	.032	5	1.35	.34	165	.50	1.10	5.03	7-19
33705	Bell Clay	.112	.056	26	1.16	.64	342	1.58	2.71	8.02	0-7
33708	Trinity Clay	.156	.120	12	1.16	.69	160	15.67	27.19	8.16	0-7
33702	Wilson Clay	.112	.046	35	.66	.26	181	.76	1.28	7.10	0-7
32644	Lake Charles Clay Loam	.155	.034	29	1.10	.13	162	.31	1.21	7.30	0-7
33126	Crockett Clay Loam	.071	.023	8	.54	—	91	—	.74	6.04	0-7

ability was measured both by the oven-dried weight of the crop and the phosphoric acid removed by the crop.

Description of Soils Used

The soils used are described as follows. The composition of these soils is given in Table 1.

31322. Amarillo silty clay loam, shallow phase, Potter County, 7 to 19 inches deep, dark red silty clay loam, taken from 1½ miles N. E. of Nash.

32644. Lake Charles Clay Loam, 0 to 7 inches deep, Galveston County surface soil, black clay loam, virgin prairie, flat, poor drainage, few sand mounds, heavy coarse grass taken from 4 mi. S. of Alto Loma.

32647. Lake Charles very fine sandy loam, 7 to 13 inches deep, Galveston County, dark gray sandy clay taken, from 5 mi. S. of Alto Loma.

32649. Lake Charles Clay, 0 to 7 inches, Galveston County, virgin prairie, hog wallow land, sample from flat place between hog wallow humps, flat—poor drainage, grayish brown clay, taken from 2 mi. E. of League City.

32650. Lake Charles Clay, 7 to 19 inches deep, Galveston County, dark grayish black clay, from 2 mi. E. of League City.

33125. Moscow fine sandy loam, 3 to 7 inches, Polk County, a gray loamy fine sand with numerous dark brown to black soft concretions, taken 6 mi. W. of Corrigan, near the Groveton Road.

33126. Crockett Clay Loam, 0 to 7 inches, Polk County, surface soil (not cultivated) a dark brownish gray heavy fine sandy loam to light clay loam, taken 2½ mi. E. of Rock Island.

33138. Wilson Clay, 7 to 14 inches, Polk County, a black heavy plastic clay, taken 3 mi. W. of Moscow on Colita road and ½ mi. N. (not cultivated).

33140. Gainer clay, 14 to 24 inches, Polk County, virgin sample, a yellow and gray mottled clay with some soft yellowish concretions, taken 200 yds. N. of East Tempe school.

33782. Wilson Clay, 0 to 7 inches, Collin County, dark gray clay, taken ½ mi. S. of Climax.

33705. Bell Clay, 0 to 7 inches, Collin County, black clay, taken 2 mi. S. E. of McKinney.

33708. Trinity Clay, 0 to 7 inches, Collin County, black clay, taken 2 mi. S. W. Climax.

Results of the Work with Soft Phosphate

The soft phosphate with colloidal clay was a sample of a shipment from Florida to Texas.

A summary is presented in Table 2 and the detailed results are given in Table 3. The addition of superphosphate is indicated by Pa, of colloidal phosphate by Co, and of finely-divided phosphate by Ru. In the seven tests with soft phosphate, the availability of the phosphoric acid compared with superphosphate as 100 ranged from 0 to 120 with an average of 40, when the gain in weight of crop was used. When the recovery of phosphoric acid was used, the availability ranged from 0 to 97, with an average of 40. A very wide variation in availability from 0 to 97 or 120, is to be noted. The lowest availability was on soil No.

Table 2. Gain due to finely-divided phosphate compared with gain due to superphosphate as 100

Laboratory number		Relative gain in crop	Relative removal of phosphoric acid	Acidity (pH)
	Soft phosphate with colloidal clay			
32647	Lake Charles very fine sandy loam	0	0	7.6
31322	Amarillo silty clay loam	2	4	7.9
33140	Gainer Clay	24	25	5.3
33125	Moscow fine sandy loam	30	40	5.0
32649	Lake Charles Clay	37	58	5.8
33138	Wilson Clay	69	55	5.7
32650	Lake Charles Clay	120	97	5.0
	Average	40	40	
	Finely ground phosphate rock			
32647	Lake Charles very fine sandy loam	0	0	7.6
32649	Lake Charles Clay	16	34	5.8
33125	Moscow fine sandy loam	34	49	5.0
32650	Lake Charles Clay	95	95	5.0
	Average	36	45	

32647, the subsoil of the Amarillo silty clay loam and soil No. 31322, the Lake Charles very fine sandy loam, while the highest was on soil No. 32650, the subsoil to the Lake Charles clay.

The soils in which the availability is low are slightly basic, as shown by the pH of 7.60 to 7.81 in Table 1, while the one with a high availability is acid, having a pH of 5.0. There are, however, two soils with a similar degree of acidity, pH 5.3 and 5.8, in which the availability is only from 30 to 37 measured by the crop and 40-58 measured by the phosphoric acid removed. The soils in Table 1 and 2 are arranged in order according to the availability of the phosphoric acid in the soft phosphate, beginning with the lowest. Aside from the general relation to the acidity or pH, no other relation can be found to the composition of the soils as shown in Table 1. The results indicate that the phosphoric acid of soft phosphate with colloidal clay has an average availability of about 40 per cent that of superphosphate, while on some acid soil it may have an availability as high as superphosphate. On neutral or basic soils it may have little or no value.

Additional Work with Soft Phosphate

Another series of pot experiments was made in which the effect of the soft phosphate upon the growth of corn and sorghum and the phosphoric acid removed was ascertained. The pot experiments were conducted by the method already described, excepting that the complete fertilizer contained one gram of dicalcium phosphate so that there could be no comparison between the same quantity of phosphoric acid in the soft

Table 3. Details of pot experiments with superphosphate (Pa), soft phosphate with colloidal clay (Co), and finely ground rock phosphate (Ru)

Additions	Crop in grams	P_2O_5 in crop, per cent	P_2O_5 in crop, grams	P_2O_5 recovered from addition, grams	Added P_2O_5 recovered, per cent	Gain in crop due to addition, grams	Relative weight of crops due to addition	Relative recovery of P_2O_5
Soil 31322								
1 N K	3.7	.31	.0115	—	—	—	—	—
2 N K	2.4	.31	.0074	—	—	—	—	—
3 N K Pa	11.0	.25	.0275	.0180	25.0	7.9	100	100
4 N K Co	3.0	.28	.0084	—	—	—	—	—
5 N K Co	3.7	.31	.0115	.0005	0.6	0.3	4	2
Soil 32647								
1 N K	2.5	.17	.0043	—	—	—	—	—
2 N K	2.5	.21	.0053	—	—	—	—	—
3 N K Pa	10.4	.23	.0239	—	—	—	—	—
4 N K Pa	10.2	.22	.0224	.0184	18.4	7.8	100	100
5 N K Co	2.2	.19	.0042	—	—	—	—	—
6 N K Co	2.2	.20	.0044	0	0	—0.3	0	0
7 N K Ru	2.3	.18	.0041	—	—	—	—	—
8 N K Ru	2.5	.19	.0048	0	0	—0.1	0	0
Soil 32649								
1 N K	12.0	.25	.0300	—	—	—	—	—
2 N K	15.2	.24	.0365	—	—	—	—	—
3 N K Pa	23.0	.26	.0598	—	—	—	—	—
4 N K Pa	31.5	.21	.0662	.0297	29.7	13.7	100	100
5 N K Co	19.5	.27	.0527	—	—	—	—	—
6 N K Co	17.9	.27	.0483	.0172	17.2	5.1	37	58
7 N K Ru	15.8	.27	.0427	—	—	—	—	—
8 N K Ru	15.7	.28	.0440	.0101	10.1	2.2	16	34
Soil 32650								
1 N K	2.5	.18	.0045	—	—	—	—	—
2 N K	2.3	.24	.0055	—	—	—	—	—
3 N K Pa	9.5	.24	.0228	—	—	—	—	—
4 N K Pa	12.2	.28	.0342	.0235	23.5	8.5	100	100
5 N K Co	12.0	.26	.0312	—	—	—	—	—
6 N K Co	13.1	.27	.0354	.0283	28.3	10.2	120	97
7 N K Ru	10.5	.31	.0326	.0276	27.6	8.1	95	95

Table 3. Details of pot experiments with superphosphate (Pa), soft phosphate with colloidal clay (Co), and finely ground rock phosphate (Ru)—Continued

Additions	Crop in grams	P_2O_5 in crop, per cent	P_2O_5 in crop, grams	P_2O_5 recovered from addition, grams	Added P_2O_5 recovered, per cent	Gain in crop due to addition, grams	Relative weight of crops due to addition	Relative recovery of P_2O_5
Soil 33125								
1 N K	3.2	.22	.0070	—	—	—	—	—
2 N K	3.3	.20	.0066	—	—	—	—	—
3 N K Pa	14.2	.23	.0327	—	—	—	—	—
4 N K Pa	18.5	.18	.0333	.0262	26.2	13.1	100	100
5 N K Co	7.8	.24	.0187	—	—	—	—	—
6 N K Co	6.5	.25	.0163	.0107	10.7	3.9	30	40
7 N K Ru	6.0	.26	.0156	—	—	—	—	—
8 N K Ru	9.5	.25	.0238	.0129	12.9	4.5	34	49
Soil 33138								
1 N K	4.8	.17	.0082	—	—	—	—	—
2 N K	2.9	.18	.0052	—	—	—	—	—
3 N K Pa	8.0	.21	.0168	—	—	—	—	—
4 N K Pa	10.2	.19	.0194	.0114	11.4	5.2	100	100
5 N K Co	5.3	.18	.0095	—	—	—	—	—
6 N K Co	9.7	.17	.0165	.0063	6.3	3.6	69	55
Soil 33140								
1 N K	3.0	.19	.0057	—	—	—	—	—
2 N K	2.4	.23	.0055	—	—	—	—	—
3 N K Pa	8.4	.19	.0160	—	—	—	—	—
4 N K Pa	8.6	.19	.0163	.0106	10.6	5.8	100	100
5 N K Co	4.2	.18	.0076	—	—	—	—	—
6 N K Co	4.0	.22	.0088	.0026	2.6	1.4	24	25

phosphate and in the dicalcium phosphate. The quantity of soft phosphate contained .10 grams of phosphoric acid. Two crops were grown, corn followed by sorghum. The percentage of phosphoric acid recovered from the soft phosphate by a single crop varied from 0 to 15.3%, the average being 4.3%. This may be compared with an average recovery of 43.9% for the phosphoric acid of superphosphate in 21 pot experiment given in Bulletin 212, and an average recovery of 9.1% for the phosphoric acid of rock phosphate. The recovery of the soft phosphate in these experiments was therefore about half of that in the experiments given in Bulletin 212.

As with the other experiments cited in the Bulletin, the highest recovery of the phosphoric acid from the soft phosphate, was on the acid soils, while the low recovery was on neutral or slightly alkaline soils. Since the soils of Texas in general are neutral rather than acid, one would expect the availability of the phosphoric acid in the soft phosphate to be low.

Finely-Ground Rock Phosphate

The finely-ground phosphate was a sample furnished by the manufacturer, and was at that time called Ruhm phosphate.

In the tests made, the availability of the phosphoric acid of the finely ground phosphate rock compared with superphosphate as 100 varies from 0 to 95 with an average of 36, when the gain in weight of the crop is used as a measure and from 0 to 95 with an average of 45 when the phosphoric acid recovered is used as a measure. The finely-ground rock phosphate has about the same availability as the soft phosphate with colloidal clay. As with the latter, the availability of the Ruhm phosphate is high in one of the acid soils and low in the neutral or alkaline soils. However, in another of the acid soils the availability was about the average.

The results indicate that the phosphoric acid of finely-divided phosphate has an average about 40 per cent of the availability of that of superphosphate, though on some acid soils it may be nearly equal to superphosphate, while on some neutral soils it may have little or no value.

SUMMARY

Soft phosphate with colloidal clay is a finely-divided phosphate which is a by-product from mining Florida rock phosphate.

The availability of the phosphoric acid in soft phosphate with colloidal clay in 7 pot experiments was found to vary from 0 to 120 with an average of 40, compared with the phosphoric acid of superphosphate as 100. The availability was low on the slightly basic soils and high on one acid soil, although it was not high on some of the acid soils.

The phosphoric acid of soft phosphate with colloidal clay in general has a much lower availability to plants than the phosphoric acid of superphosphate and its availability seems to be lower on neutral or basic soils, such as generally prevail in Texas.

Table 4. Effect of 0.1 gm. soft phosphate upon crop growth and recovery of phosphoric acid

Laboratory number	Crop	Complete fertilizer average crop, gm.	No phosphate			Soft phosphate			Gain of P_2O_5 due to phosphate, gm.	Per cent P_2O_5 recovered from soft phosphate
			Crop, gm.	P_2O_5 per cent	P_2O_5 gms. average	Crop, gm.	P_2O_5 per cent	P_2O_5 gm. average		
32644	Corn	39.2	10.8	.26		10.8	.29	.0313		
	"		11.1	.30	.0307				.0006	0.6
32644	Sorghum	35.0	24.2	.13		22.0	.18	.0396	.0072	7.2
	"		23.8	.14	.0324					
33126	Corn	33.9	4.5	.24		8.2	.22	.0180		
	"		2.7	.22	.0084				.0096	9.6
33126	Sorghum	28.4	8.3	.25		18.0	.20	.0360		
	"		10.3	.20	.0207				.0153	15.3
33702	Corn	37.2	24.1	.27		22.8	.33	.0752		
	"		22.0	.31	.0667	18.0	.35	.0691	.0014	1.4
33702	Sorghum	35.5	30.6	.28		29.2	.27	.0788		
	"		31.5	.29	.0896	21.0	.32	.0730	.0044	4.4
33705	Corn	26.6	22.0	.34		20.0	.34	.0680		
	"		14.2	.43	.0680				0	0
33705	Sorghum	37.3	40.6	.25		40.2	.24	.0965	0	
	"		35.5	.27	.0987					0
33708	Corn	27.9	18.2	.46		16.5	.42	.0693	0	0
	"		14.8	.49	.0781					
33708	Sorghum	31.1	29.0	.40		24.5	.46	.1127	.0047	4.7
			27.0	.37	.1080					
	Average								.0043	4.3

The phosphoric acid of rock phosphate which has been very finely ground has been claimed to have a high availability, but in five pot experiments the availability of the phosphoric acid of finely ground rock phosphate was only about 40 per cent of that of superphosphate. Its availability seemed to be low on neutral or basic soils and high on acid soils.

On some acid soils, the availability of the phosphoric acid of both soft phosphate with colloidal clay and finely ground rock phosphate is equal to that of superphosphate, but on other acid soils its availability is decidedly less than that of superphosphate.

The results on the same soils are similar whether the availability is measured by the relative gain in weight of the crop or by the quantity of phosphoric acid taken up by the plant.

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