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TEXAS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 223 DECEMBER, 1917

DIVISION OF CHEMISTRY

EFFECTS OF LIME AND CARBONATE OF LIME ON ACID PHOSPHATE

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EFFECTS OF LIME AND CARBONATE OF LIME ON ACID PHOSPHATE

BY

G. S. FRAPS, PH. D., CHEMIST IN CHARGE; STATE CHEMIST.

In practically all books on agricultural chemistry and on fertilizers, it is stated that lime, limestone, wood ashes, Thomas phosphate and similar materials should never be mixed with acid phosphate. The reason for this is obvious. The acid phosphate has been made by treating phosphate rock with sulphuric acid. The effect of the lime or limestone would be to neutralize the action of the sulphuric acid and change the phosphoric acid back to the less soluble forms.

Limestone and hydrated lime, nevertheless, have been and are being used as additions to acid phosphate. The addition is made to some extent as a filler. Another object is to improve the physical character so that the mixture will not become damp, sticky, and difficult to apply, especially in wet localities. It is, of course, a decided advantage to have a fertilizer in such good mechanical condition that it may be easily placed in the soil, or distributed easily in fertilizer drills.

Some commercial chemists have gone so far as to state that the addition of lime to fertilizers is of advantage in that it would add limestone needed by the soil. However, 200 pounds of acid phosphate containing 10 per cent. carbonate of lime would only introduce 20 pounds of limestone into the soil. If the soil is in need of lime, it is hardly advisable to use less than 2,000 pounds per acre of limestone.

It is a matter of considerable practical importance to ascertain to what extent the addition of lime or limestone to acid phosphate is harmful or harmless.

EFFECT OF CARBONATE OF LIME ON WATER-SOLUBLE AND INSOLUBLE PHOSPHORIC ACID.

Table 1 shows the results of some experiments on mixing acid phosphate with precipitated calcium carbonate. Fifty grams of the acid phosphate were mixed with from 0.5 grams to 10 grams of calcium carbonate, and analysis made immediately. The mixtures were allowed to stand and analyses made at the intervals indicated. The results are given in percentages of the mixtures used, and are not calculated back to the original acid phosphate. The acid phosphate used in each series was different and had a different water content. In series F, it contained 12.9 per cent. water.

Table 1.—Effect of carbonate of lime on phosphoric acid of acid phosphate.

Series.	Added to 50 gms.	0 days.	1 day.	2 days.	5 days.	10 days.	20 days.	50 days.	80 days.
	Water—Soluble Phosphoric Acid—								
A	0	13.73	13.75	13.80	13.71	13.88	13.75	.....	.....
	0.5 gm	13.50	13.51	13.50	13.16	13.30	13.33	.....	.....
	1.0 gm	13.65	13.21	13.45	13.98	13.18	13.11	.....	.....
	2.5 gms	12.93	12.29	12.15	11.65	11.60	11.95	.....	.....
	5.0 gms	11.98	10.94	10.70	12.59	9.89	9.16	.....	.....
	10.0 gms	11.33	9.09	9.16	8.20	6.66	4.99	.....	.....
	Insoluble Phosphoric Acid—								
A	0	.13	.13	.18	.11	.12	.05	.....	.....
	0.5 gm	.10	.14	.20	.14	.18	.22	.....	.....
	1.0 gm	.16	.26	.26	.20	.20	.23	.....	.....
	2.5 gms	.19	.36	.38	.48	.60	.73	.....	.....
	5.0 gms	.15	.30	.49	.59	.81	1.03	.....	.....
	10.0 gms	.13	.34	.51	.69	1.01	1.56	.....	.....
	Water Soluble—								
B	0	12.43	12.54	12.90	13.45	12.20	11.97	.....	.....
	0.5 gm	12.38	12.66	12.43	12.65	11.95	11.67	.....	.....
	1.0 gm	12.43	12.18	12.04	12.05	11.57	11.35	.....	.....
	2.5 gms	11.49	10.31	10.18	10.48	9.83	9.54	.....	.....
	5.0 gms	10.11	4.18	4.28	3.75	3.48	3.31	.....	.....
	10.0 gms	9.44	1.09	1.78	1.43	1.08	0.79	.....	.....
	Insoluble—								
B	0	.15	.14	.13	.25	.13	.14	.....	.....
	0.5 gm	.18	.14	.14	.25	.15	.15	.....	.....
	1.0 gm	.14	.23	.14	.28	.16	.16	.....	.....
	2.5 gms	.16	.26	.17	.26	.19	.23	.....	.....
	5.0 gms	.19	.28	.18	.28	.23	.26	.....	.....
	10.0 gms	.21	.36	.23	.39	.33	.43	.....	.....
	Water Soluble—								
C	0	3.98	4.20	3.98	3.90	3.90	.....	.....	.....
	0.5 gm	3.60	3.55	3.55	3.23	3.18	.....	.....	.....
	1.0 gm	3.35	3.18	2.83	2.63	2.58	.....	.....	.....
	2.0 gms	2.90	2.50	2.13	1.60	1.35	.....	.....	.....
	5.0 gms	1.68	1.48	1.23	.95	1.00	.....	.....	.....
	10.0 gms	1.40	1.23	1.00	.80	.18	.....	.....	.....
	Insoluble—								
C	0	.24	.23	.24	.26	.31	.....	.....	.....
	0.5 gm	.25	.28	.23	.24	.30	.....	.....	.....
	1.0 gm	.29	.26	.26	.26	.38	.....	.....	.....
	2.0 gms	.23	.33	.29	.34	.55	.....	.....	.....
	5.0 gms	.41	.44	.33	.43	.71	.....	.....	.....
	10.0 gms	.45	.43	.39	.35	.51	.....	.....	.....
	Water Soluble—								
D	0	13.92	13.71	13.76	13.80	14.09	13.70	.....	.....
	0.5 gm	13.72	13.59	13.57	13.46	13.77	13.51	.....	.....
	1.0 gm	13.27	12.71	Lost	12.45	12.76	12.59	.....	.....
	2.0 gms	12.64	11.10	10.49	10.35	10.30	9.47	.....	.....
	5.0 gms	10.32	7.42	6.69	4.97	4.27	3.55	.....	.....
	10.0 gms	9.07	4.66	3.62	2.32	1.37	1.10	.....	.....
	Insoluble—								
D	0	.17	.16	.16	.16	.19	.17	.....	.....
	0.5 gm	.16	.18	.18	.15	.19	.17	.....	.....
	1.0 gm	.17	.19	.20	.17	.20	.18	.....	.....
	2.0 gms	.16	.22	.26	.25	.31	.27	.....	.....
	5.0 gms	.17	.24	.34	.47	.64	.64	.....	.....
	10.0 gms	.16	.26	.34	.47	.72	.81	.....	.....
	Water Soluble—								
E	0	11.95	11.90	11.90	11.95	12.00	11.79	11.94	.....
	0.5 gm	11.71	11.79	11.75	11.62	11.91	11.77	11.99	.....
	1.0 gm	11.25	11.17	11.01	11.20	11.16	11.00	.....	.....
	2.0 gms	10.69	9.87	9.55	9.47	9.44	9.02	9.54	.....
	5.0 gms	6.85	4.84	4.21	3.44	3.09	2.65	2.21	1.96
	10.0 gms	4.06	2.44	1.47	.54	.20	.91	.67	.60
	Insoluble—								
E	0	.25	.32	.22	.25	.28	.38	.39	.....
	0.5 gm	.27	.35	.23	.36	.36	.42	.41	.....
	1.0 gm	.32	.34	.34	.38	.34	.41	.42	.....
	2.0 gms	.30	.40	.33	X	.44	.51	.61	.....
	5.0 gms	.37	.45	.38	.53	.64	.86	1.01	1.15
	10.0 gms	.47	.56	.56	.67	.76	1.37	1.99	3.39

Table 1.—Effect of carbonate of lime on phosphoric acid of acid phosphate.—Continued.

Series.	Added to 50 gms.	0 days.	1 day.	2 days.	5 days.	10 days.	20 days.	50 days.	80 days.
F	Water Soluble—								
	.....	12.12	11.92	12.27	11.47	11.75	11.27	.....	.....
	0.5 gm.....	11.56	11.27	11.56	10.67	10.60	10.65	.....	.....
	1.0 gm.....	10.87	10.77	10.34	9.76	9.65	9.54	.....	.....
	2.0 gms.....	9.61	9.19	8.59	7.61	7.20	6.94	.....	.....
	5.0 gms.....	6.61	5.90	4.57	2.84	2.17	1.69	1.05	.....
	10.0 gms.....	3.45	2.25	1.76	1.30	1.11	1.12	.87	.....
F	Insoluble—								
	No addition.....	.61	.63	.72	.71	.77	.69	.....	.....
	0.5 gm. Ca CO3....	.64	.72	.81	.67	.77	.79	.....	.....
	1.0 gm. Ca CO3....	.78	.68	.78	.69	.84	.80	.....	.....
	2.0 gms. Ca CO3....	.74	.82	.76	.78	.90	.82	.....	.....
	5.0 gms. Ca CO3....	.71	.76	.77	.83	.87	.98	1.99	.....
	10.0 gms. Ca CO3....	.76	.81	.85	.81	.94	.99	2.12	.....

An examination of the table shows that water-soluble phosphoric acid decreases much more rapidly than the insoluble phosphoric acid. That is to say, the carbonate of lime acts first upon the water-soluble phosphoric acid, and much more slowly upon the citrate-soluble.

EFFECT OF HYDRATED LIME.

The experiments with hydrated lime are similar to those with carbonate of lime, 50 grams acid phosphate being used and the results reported in the percentages of the mixture. Commercial hydrated lime was used. (See Table 2.)

Table 2.—Effect of hydrated lime on phosphoric acid of acid phosphate.

Series.	Addition.	0 day.	1 day.	2 days.	5 days.	10 days.	20 days.
G	Water—Soluble—						
	0.....	12.99	12.96	13.08	13.10	13.08	12.98
	0.5 gm.....	12.96	12.86	13.13	13.08	12.95	13.00
	1.0 gm.....	12.48	12.40	12.49	12.40	12.43	12.23
	2.5 gms.....	7.91	7.55	7.45	7.57	7.38	7.58
	5.0 gms.....	1.94	1.14	1.18	11.15	.88	1.06
	10.0 gms.....	.00		.00	.00	.00	.00
G	Insoluble—						
	0.....	.10	.14	.16	.14	.17	.12
	0.5 gm.....	.10	.14	.15	.17	.14	.24
	1.0 gm.....	.13	.15	.23	.20	.21	.24
	2.5 gms.....	.19	.21	.28	.25	.29	.30
	5.0 gms.....	.52	.32	.48	.32	.45	.48
	10.0 gms.....	1.46	1.17	2.26	3 23	4.30	10.50
H	Water—Soluble—						
	0.....	4.20	4.08	3.90	3.95	4.00	.....
	0.5 gm.....	2.95	2.80	2.65	2.55	2.65	.....
	1.0 gm.....	1.50	1.40	1.28	1.10	1.35	.....
	2.0 gms.....	.58	.58	.53	.53	.65	.....
	5.0 gms.....	.05	.05	.03	.05	.03	.....
	10.0 gms.....	.05	.05	.03	.05	.03	.....
H	Insoluble—						
	0.....	.36	.30	.23	.25	.31	.....
	0.5 gm.....	.34	.46	.34	.34	.41	.....
	1.0 gm.....	.56	.56	.41	.40	.60	.....
	2.0 gms.....	.....	1.34	1.39	1.61	1.84	.....
	5.0 gms.....	.41	.98	1.03	.93	1.13	.....
	10.0 gms.....	.45	.81	.76	.76	1.06	.....

Table 2.—Effect of hydrated lime on phosphoric acid of acid phosphate—Continued.

Series.	Addition.	0 day.	1 day.	2 days.	5 days.	10 days.	20 days.
	Water—Soluble—						
I	0	13.82	13.56	14.02	13.69	13.89	13.60
	0.5 gm	13.46	13.50	13.46	13.27	13.61	13.02
	1.0 gm	12.24	11.91	11.60	11.90	11.95	11.64
	2.0 gms	9.30	8.86	9.07	8.79	8.76	8.66
	5.0 gms	1.62	1.16	1.15	1.08	1.02	.95
	10.0 gms	.06	.05	.02	.01	.02	.04
	Insoluble—						
I	0	.17	.16	.17	Lost	.20	.16
	0.5 gm	.17	.19	.18	.17	.20	.17
	1.0 gm	.20	.20	.21	.17	.21	.19
	2.0 gms	.17	.24	.22	.19	.23	.20
	5.0 gms	.49	.49	.51	.44	.52	.42
	10.0 gms	.61	.67	1.23	1.50	1.99	2.39

As was to be expected, the effect of the hydrated lime was more vigorous than the carbonate of lime, and a more rapid decrease in water-soluble phosphoric acid occurs, together with a greater increase in insoluble phosphoric acid.

The Reactions.

The reactions thus take place in two stages:

First stage:

$$CaH_4P_2O_8+CaCO_3=Ca_2H_2P_2O_8+H_2O+CO_2$$
$$CaH_4P_2O_8+Ca(OH)_2=Ca_2H_2P_2O_8+2H_2O$$

Thus 100 parts carbonate of lime or 84 parts of hydrated lime react with 142 parts phosphoric acid (P_2O_5). Thus 1 per cent. carbonate of lime, if fully acting, would change 1.42 per cent. phosphoric acid from the water-soluble to the citrate-soluble form.

Second stage:

$$Ca_2H_2P_2O_8+CaCO_3=Ca_3P_2O_8+H_2O+CO_2$$

Thus 1 per cent. carbonate of lime, reacting fully, would change 1.42 per cent. phosphoric acid from the citrate-soluble to the insoluble condition. If the carbonate of lime carried out both reactions, 1 per cent. would change .71 per cent. phosphoric acid from the water-soluble to the insoluble condition.

These considerations show that the addition of 10 per cent. carbonate of lime would be sufficient to change 14.2 per cent. water-soluble phosphoric acid to the reverted condition, or 7.1 per cent. from the water-soluble to the insoluble condition, if the reaction progressed to the fullest extent possible. This, however, is not to be expected within solid mixtures, especially if the calcium carbonate is coarsely ground, as is the case when it is used as a filler.

Table 3.—Change of phosphoric acid due to carbonate of lime in 20 days.

	Addition.	Water—soluble.	Insoluble.	Total.	Calculated change.
A	5 per cent	1.22	.72	1.94	7.10
	10 per cent	2.57	1.10	3.67	14.20
	20 per cent	8.20	1.68	9.88	28.40
B	5 per cent	1.92	.14	2.06	7.10
	10 per cent	8.29	.15	8.44	14.20
	20 per cent	10.97	.40	11.37	28.40
D	5 per cent	3.74	.12	3.86	5.68
	10 per cent	9.75	.54	10.29	14.20
	20 per cent	12.33	.83	13.16	28.40

It is of some interest to inquire how far the reaction progressed in our experiment. Table 3 shows the change in 20 days due to carbonate of lime, calculated back to 100 parts acid phosphate. It is easily seen from the table that the reaction is not complete in 20 days; that the reaction is greatest with the water-soluble phosphoric acid, but that the citrate-soluble phosphoric is also affected.

OBJECTS OF USING CARBONATE OF LIME IN A FERTILIZER.

There are two objects in using carbonate of lime in a fertilizer: first, to dry it out, so that it will drill more easily; second, to act as a filler and so secure the desired composition.

Acid phosphate made with an excess of acid, or poorly cured, contains some free phosphoric acid. Free phosphoric acid attracts moisture from the air and thus makes the phosphate damp and sticky. The addition of carbonate of lime to such phosphate will convert the phosphoric acid into monocalcium phosphate, which does not attract moisture, and the physical condition of the fertilizer would thus be improved.

Calcium carbonate does not absorb moisture, and in its reaction with phosphoric acid, monocalcium phosphate, or dicalcium phosphate, it produces moisture. It is therefore difficult to see how the addition of carbonate of lime in excess of the quantity needed to convert free phosphoric acid into monocalcium phosphate, would be of any advantage in drying the fertilizer. The amount of carbonate of lime required to change the free phosphoric acid should be comparatively small. As already shown, 1 per cent. would change 1.42 per cent. Two or three per cent. carbonate of lime should be sufficient for this purpose, unless the acid phosphate is very badly made indeed.

Free phosphoric acid may be estimated by drying the sample, extracting the phosphoric acid with anhydrous ether, and estimating the quantity dissolved by the usual method. Table 4 shows the quantity of free phosphoric acid in some acid phosphates.

Table 4.—Free phosphoric acid in acid phosphates.

Labratory Number.		Per cent.
679	0	.72
679	With 1 per cent carbonate of lime	.08
712	0	.44
712	With 1 per cent carbonate of lime	.39
25976	0	.31
26187	0	.54

The use of calcium carbonate as a filler is not to be commended. There is no reason why a filler open to fewer objections should not be used.

OBJECTIONS TO USE OF CALCIUM CARBONATE.

There can be little objection to the use of 3 or 4 per cent. calcium carbonate in an acid phosphate for the purpose of making it drier and more easily applied. This quantity may slightly reduce the water-soluble phosphoric acid but will hardly affect the reverted.

There are decided objections to the use of more than 4 per cent. calcium carbonate in an acid phosphate. In the first place, the water-soluble phosphoric acid will be largely changed, converting it into less soluble forms, less fitted for distribution in the soil. In the second place, it will reduce the available phosphoric acid by increasing the insoluble.

The latter effect will depend upon the mechanical condition of the carbonate of lime and the character of the acid phosphate. A coarsely ground limestone will not act so much as the finely ground precipitated carbonate of lime used in these experiments. If the pile of acid phosphate heats, the reaction will go further than if it does not heat.

In some cases, fertilizer manufacturers are surprised to find their goods run below guarantee and claim that the State analysis is not correct, when, as a matter of fact, the trouble is due to the limestone filler they used. In the season of 1915-16, we found two samples of acid phosphate guaranteed 16 per cent. available but containing only 13 per cent. available. Further examination showed the presence of carbonate of lime. The total phosphoric acid was 18 per cent., and the insoluble was 5 per cent. The deficiency was due to reversion of the phosphoric acid caused by the carbonate of lime.

DETECTION AND ESTIMATION.

Limestone in a fertilizer may easily be detected by pouring dilute acid on the fertilizer. It may be estimated by the various methods for estimating carbonates, measuring the carbon dioxide evolved or otherwise. It is not necessary to describe these well known methods here. If the acid phosphate has used all the calcium carbonate, it cannot, of course, be estimated. The estimation shows the calcium carbonate which remains unchanged.

Table 5 gives the carbonate of lime found in various commercial acid phosphates.

Table 5.—Carbonate of lime in commercial acid phosphates.

Laboratory number.	Per cent.
26075	4.5
26206	1.3
26211	5.8
26221	3.2
26208	4.1
26168	3.6

It is a question whether part of the reaction does not take place in the filter paper, when the fertilizer is being washed with water to remove the water-soluble phosphoric acid.

To test this, we mixed carbonate of lime with acid phosphate and determined carbon dioxide directly in one portion; in another portion we determined carbon dioxide after washing the mixture with water, as in the estimation of water-soluble phosphoric acid.

Table 6.—Carbonate of lime before and after washing the mixture.

Laboratory number.	Carbonate of lime.			Water-soluble phosphoric acid.			
	Dry.	Washed.	Loss.	Original.	Corrected original.	Washed.	Loss.
26097	12.9	12.8	0.1	12.10	10.01	8.42	1.59
26192	14.5	13.9	0.6	8.40	7.00	6.27	0.73
26225	13.9	13.2	0.2	12.92	10.77	9.66	1.11

The results are in Table 6. There was a slight loss of carbonate of lime during the washing, but this is within the limits of error of the work, so we may consider that little if any reaction took place on the filter paper. Some reaction had taken place, however.

In another experiment, we mixed 0.5 grams dry carbonate of lime with 2.5 grams acid phosphate in a bottle connected with a gas measuring apparatus. The amount of carbon dioxide evolved in 10 minutes was 2.5 c.c. equal to about 0.8 per cent. The reaction, of course, goes on slowly.

EFFECT OF SALTS.

Table 7 shows the effect of nitrate of soda and sulphate of potash on the insoluble phosphoric acid. Two grams of carbonate of lime and 0.5 gram sodium nitrate or sulphate of potash were added to 2 grams acid phosphate, mixed well, and allowed to stand seven days.

The nitrate of soda, which is hygroscopic, increased the insoluble phosphoric acid, due to the action of the lime, decidedly more than did the sulphate of potash.

Table 7.—Effect of nitrate of soda and sulphate of potash on the insoluble phosphoric acid.

	A	B	C
Carbonate of lime and nitrate of soda	6.95	4.07	5.05
Carbonate of lime and sulphate of potash	3.40	2.87	3.82

EFFECT ON AVAILABILITY.

Kellner and Bottcher (Jahnesber Agr. Chem., 1901, 112) found in pot experiments on mustard that lime decreases the availability of phophates. They used large quantities of lime. (See Table 8.)

Table 8.—Effect of carbonate of lime on availability of phosphoric acid.

	Super phosphate.	Thomas phosphate.	Bone meal.
No lime	100	100	100
Carbonate of lime 15 gms	77.7	81.7	72.6
Carbonate of lime 30 gms	75.5	81.5	50.0

In another experiment, they found the availability of double phosphate with lime was 89, when that without lime was placed at 100. In these experiments, large amounts of lime were used, compared with the amount of phosphate.

POT EXPERIMENTS.

We made some pot experiments to test the effect of lime on acid phosphate, but we are not altogether satisfied with the way some of these crops grew.

Details:

Soils 3653, 4643, 4580, 4596, 4581, 4589, 4591. Additions:

Ac 1 gram acid phosphate.

AcL 0.1 gram calcium carbonate mixed with the acid phosphate before putting in the soil.

One gram sulphate of potash and 1 gram ammonium nitrate added to all pots.

Corn planted May 8, harvested July 10-14, 1911. Four stalks.

One gram ammonium nitrate added to all pots. Sorghum planted July 25, harvested October 7, 1911. No. 2 Ac replanted July 31.

Soil 3976 planted May 8; second crop planted August 9. Ac 2L had 0.2 grams carbonate of lime added to the acid phosphate. Ac 3L, 0.3 grams carbonate of lime added to the 1 gram acid phosphate.

In another series, acid phosphate was compared with acid phosphate mixed with 10 per cent. carbonate of lime. There were used 0.259 grams acid phosphate or 0.286 grams phosphate with carbonate of lime, which contained an equal amount of available phosphoric acid. The pots received 1 gram each of sulphate of potash and ammonium nitrate, contained 5,000 grams soil, and were planted with corn April 20, 1915, and harvested June 21, 1915. One gram each ammonium nitrate and sulphate of potash were added, planted June 22; harvested August 27, 1915.

Results

A summary of the results is given in Tables 9 and 10. Details of the test are given in Tables 11 and 12.

Table 9.—*Loss of phosphoric acid due to the addition of 10 per cent. carbonate of lime.*

Lab. No.		Corn.	Sorghum.	Total.	Corn removed without lime.
3653	1911 series	.0023	.0126	.0149	.0599
4604	1911 series	.0013	.0128	.0141	.0580
4643	1911 series	.0085	0	.0085	.0457
4580	1911 series	.0084	0	.0084	.0665
3976	1911 series	.0040	0	.0040	.0168
4596	1911 series	0	.0004	.0004	.0284
4581	1911 series	.0285	0	.0285	.2261
4584	1911 series	0	.....	0	.0480
	Average gms	.0066	.0037	.0099	.0687
9272	1915 series	0	0	0	.0172
9275	1915 series	0	.....	0	.0195
9276	1915 series	0	.....	0	.0127
9282	1915 series	.0009	.0003	.0012	.0177

Table 10.—Loss of phosphoric acid due to 20 per cent. carbonate of lime.

Lab. No.		Corn.	Sorghum.	Tota .	Corn without lime.
4604	1911 series	.0004	0	.0004	.0580
3976	1911 series	.0015	.0011	.0026	.0168
4596	1911 series	0	0	0	.0284
4581	1911 series	.0433	0	.0433	.2261
	Average gms	.0113	.00027	.0116	.0823

The crops did not grow as well as they should in the series of 1915. The summary shows that there is an average loss due to the addition of the lime to the acid phosphate, small in some cases, large in others, but on the average sufficient to make a decided difference in the value of the fertilizer. That is to say, the addition of 10 per cent. or 20 per cent of carbonate of lime to acid phosphate reduces the value of the fertilizer to crops.

Table 11.—Details of pot experiments, 1911.

Lab. No.		Crop.	Per cent. P_2O_5	Gm. P_2O_5	Average.	Loss.
3653	1-AC corn	34.5	.16	.0552	.0599	
	2-AC	40.4	.16	.0646		
	3-ACL	39.6	.14	.0554	.0576	.0023
	4-ACL	31.3	.19	.0595		
3653	1-AC sorghum	16.7	.19	.0317	.0356	
	2-AC	19.7	.20	.0391		
	3-ACL	10.9	.19	.0207	.0230	.0126
	4-ACL	14.0	.18	.0252		
4604	1-AC corn	26.1	.22	.0574	.0580	
	2-AC	34.4	.16	.0585		
	3-ACL	24.2	.23	.0557	.0557	.0013
	4-ACL	19.2	.29	.0557		
	5-ACLL	26.2	.22	.0576	.0576	.0004
4604	1-AC sorghum	31.6	.19	.0600		
	2-AC	31.2	.20	.0624	.0612	
	3-ACL	25.3	.21	.0531		
	4-ACL	29.1	.15	.0436	.0484	.0128
	5-AC2L	28.9	.22	.0656	.0656	0

Table 11.—Details of pot experiments.—Continued.

Lab. No.		Crop.	Per cent. P_2O_5	Gm. P_2O_5	Average.	Loss.
4643	1-AC corn	36.8	.12	.0442		
	2-AC	34.0	.14	.0476	.0457	
	3-ACL	31.5	.12	.0378		
	4-ACL	30.6	.12	.0367	.0372	.0085
4643	1-AC sorghum	20.0	.13	.0260		
	2-AC	12.8	.17	.0217	.0239	
	3-ACL	18.6	.14	.0260		
	4-ACL	17.1	.18	.0308	.0284	.0000
4580	1-AC corn	24.2	.30	.0726		
	2-AC	24.2	.25	.0605	.0665	
	3-ACL	21.6	.25	.0540		
	4-ACL	22.2	.28	.0581	.0622	.0084
4580	1-AC sorghum	23.7	.27	.0640		
	2-AC	22.2	.23	.0511	.0526	
	3-ACL	23.0	.24	.0552		
	4-ACL	24.5	.24	.0588	.0570	0
3976	1-AC corn	10.1	.17	.0172		
	2-AC	11.0	.15	.0165	.0168	
	3-ACL	11.8	.14	.0165		
	4-ACL	7.5	.12	.0090	.0128	.0040
	5-AC2L	8.5	.17	.0145		
	6-AC2L	9.5	.17	.0162	.0153	.0015
3976	1-AC sorghum	11.5	.16	.0184		
	2-AC	6.8	.21	.0143	.0164	
	3-ACL	1.4	.17	.0024		
	4-ACL	12.0	.16	.0192	.0192	0
	5-AC2L	5.3	.20	.0106		
	6-AC2L	9.6	.20	.0192	.0153	.0011
4596	1-AC corn	28.6	.10	.0286		
	2-AC	25.6	.11	.0282	.0284	
	3-ACL	24.8	.12	.0298		
	4-ACL	30.7	.10	.0307	.0303	0
	5-AC2L	26.4	.11	.0290	.0290	0
4596	1-AC sorghum	20.2	.14	.0283		
	2-AC	18.3	.13	.0238	.0261	
	3-ACL	19.6	.12	.0235		
	4-ACL	19.7	.14	.0276	.0257	.0004
	5-AC2L	20.9	.14	.0293	.0293	0
4581	1-AC corn	54.4	.42	.2285		
	2-AC	55.9	.40	.2236	.2261	
	3-ACL	52.6	.42	.2209		
	4-ACL	51.1	.38	.1942	.1976	.0285
	5-AC2L	40.8	.39	.1591		
	6-AC2L	49.1	.38	.1866	.1728	.0433
	7-AC3L	50.6	.37	.1872	.1872	.0389
4581	1-AC sorghum	8.3	.58	.0481		
	2-AC	15.0	.53	.0795	.0638	
	3-ACL	13.7	.51	.0699		
	4-ACL	17.8	.53	.0943	.0737	0
	5-AC2L	16.3	.51	.0831		
	6-AC2L	14.4	.52	.0749	.0790	0
	7-AC3L	18.3	.48	.0878	.0878	0
4584	1-AC corn	21.0	.20	.0420		
	2-AC	24.5	.22	.0539	.0480	
	3-ACL	24.5	.20	.0490		
	4-ACL	23.9	.23	.0550	.0520	0

Table 12.—Details of pot experiments, 1915.

Lab. No.		Weight crop.	Per cent. P_2O_5	Gm. P_2O_5	Average.	Loss.
9172	1-O corn	6.1	.20	.0122		
	2-O	6.2	.15	.0093	.0108	
	3-AC	6.5	.26	.0169		
	4-AC	7.4	.26	.0174	.0172	
	5-ACL	7.9	.26	.0205		
	6-ACL	6.8	.25	.0170	.0188	0
	1-O sorghum	1.9	.15	.0029		
	2-O	3.4	.14	.0048	.0039	
	3-AC	10.5	.13	.0137		
	4-AC	6.5	.16	.0104	.0121	
	5-ACL	6.3	.23	.0145		
	6-ACL	9.7	.22	.0213	.0179	0
9275	1-O corn	9.3	.14	.0130		
	2-O	10.0	.18	.0180	.0155	
	3-AC	11.8	.18	.0202		
	4-AC	10.4	.18	.0187	.0195	
	5-ACL	12.7	.22	.0279		
	6-ACL	12.4	.19	.0236	.0258	0
	1-O sorghum	0	.....	.....	.....	.....
	2-O	0	.....	.....	.....	.....
	3-AC	.2	.....	.....	.....	.....
	4-AC	.7	.....	.....	.....	.....
	5-ACL	2.7	.....	.....	.....	.....
	6-ACL	3.7	.....	.....	.....	.....
9276	1-O corn	6.7	.17	.0114		
	2-O	6.1	.16	.0098	.0106	
	3-AC	6.8	.19	.0129		
	4-AC	7.0	.19	.0124	.0127	
	5-L	6.0	.21	.0126		
	6-L	6.3	.20	.0126	.0126	0
	1-O sorghum	2.7	.....	.....	.....	.....
	2-O	3.5	.....	.....	.....	.....
	3-AC	7.0	.....	.....	.....	.....
	4-AC	3.7	.....	.....	.....	.....
	5-L	6.4	.....	.....	.....	.....
	6-L	4.4	.....	.....	.....	.....
9282	1-O corn	5.6	.23	.0129		
	2-O	5.8	.23	.0133	.0131	
	3-AC	6.5	.27	.0176		
	4-AC	6.1	.29	.0177	.0177	
	5-L	7.9	.22	.0174		
	6-L	5.6	.29	.0162	.0168	.0009
	1-O sorghum	3.7	.14	.0052		
	2-O	3.0	.14	.0042	.0047	
	3-AC	7.0	.20	.0140		
	4-AC	8.1	.13	.0105	.0123	
	5-L	3.5	.20	.0070		
	6-L	8.5	.20	.0170	.0120	.0003

USE OF CARBONATE OF LIME IN MIXED FERTILIZERS.

The use of carbonate of lime in mixed fertilizers has been advocated by some for the purpose of correcting the acidity of the soil and also for releasing potash of the soil. We have shown in Texas Bulletin No. 190 that lime has little effect in rendering soil potash available, contrary to preconceived ideas on the subject. If needed to correct soil acidity, lime should be added separately, and not mixed with fertilizer which it affects injuriously.

In Bulletin No. 220 of the North Carolina Department of Agriculture, J. L. Burgess, Agronomist, discusses this subject and concludes that limestone is beneficial in a fertilizer and will replace potash. With this conclusion, we are obliged to dissent. He recommends various mixtures of fertilizing materials, with from 600 to 1200 pounds ground

limestone, mostly of 1200 pounds. We recommend that limestone, in cases where needed, be applied separately from fertilizers. The question is not whether lime benefits the soil or not, but whether the limestone, if needed, be applied mixed with a fertilizer, or separately.

The use of ground limestone in a fertilizer in excess of 3 or 4 per cent. is objectionable for the following reasons:

1. It will revert the water-soluble phosphoric acid to citrate-soluble.
2. It will revert a small or larger part of the phosphoric acid to an insoluble form.
3. It will counteract the purpose of putting in the sulphuric acid with the rock phosphate in the original manufacture of the acid phosphate.
4. It will cause the application of lime to soils which already contain an abundance, or its application in insufficient amounts to soils which really need lime.
5. There is no reason to believe that the carbonate of lime will release any additional amount of soil potash.
6. The use of carbonate of lime as a filler in fertilizers involves the danger that the fertilizer will fall below guarantee in available phosphoric acid.

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SUMMARY

Carbonate of lime added to an acid phosphate acts first upon any free phosphoric acid present, next on the water-soluble phosphoric acid, and much less readily upon the citrate-soluble phosphoric acid to form insoluble phosphoric acid. These three reactions may go on at the same time.

Carbonate of lime may be used as a drier for acid phosphate in quantity sufficient to combine with the free phosphoric acid, which attracts moisture. The use of more than 3 or 4 per cent. is not advisable.

Carbonate of lime liberates water when reacting upon acid phosphate.

Unchanged carbonate of lime in a fertilizer may be estimated by gasometric or gravimetric methods.

Some samples of acid phosphate which fell badly below guarantee in available phosphoric acid contained carbonate of lime and a high percentage of insoluble phosphoric acid.

The use of carbonate of lime as a filler is likely to cause the fertilizer to fall below guarantee in available phosphoric acid.

Nitrate of soda increased the deleterious effect of carbonate of lime.

Acid phosphate mixed with lime was less available to corn and sorghum grown in pot experiments than the acid phosphate alone. The pot experiments were not entirely satisfactory.

The use of carbonate of lime in preparing home mixed fertilizers is not to be advised. When lime is needed by the soil, it should be applied separately from the fertilizer, and at different times.

Hydrated lime should not be used in mixed fertilizers.