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A. B. CONNER, DIRECTOR
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DIVISION OF CHEMISTRY

The Fertilizing Value of Greensand

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Greensand, a mineral containing phosphoric acid and potash, is extensively distributed through Texas. Some deposits containing 3 to 6 per cent of total phosphoric acid and 3 to 6 per cent of total potash have been found in Bexar and other counties, but the greensand in East Texas contains much smaller percentages of phosphoric acid and potash.

The potash in greensand is not soluble in water, as is the case with commercial fertilizers, but is almost completely soluble in strong acids. The phosphoric acid is not highly available, like that in commercial fertilizers, but is soluble in acids.

Pot experiments on three soils were made for the purpose of ascertaining the availability to plants of the phosphoric acid and potash of greensand. The maximum availability of the phosphoric acid in greensand was 40 per cent of that of superphosphate, while the minimum was zero. The maximum availability of the potash of greensand compared with that of potash salts was 12 per cent. A liberal average availability was 10 per cent for phosphoric acid and 8 per cent for potash.

The value of greensand containing 5 per cent each of phosphoric acid and potash, compared with a commercial fertilizer of the same composition which would have a valuation of $12.00 a ton at the present time, would be $3.12 a ton if the maximum availability of the potash and phosphoric acid in greensand is used. If the availability of 10 per cent for phosphoric acid and 8 per cent for potash is used, the comparative value of greensand containing 5 per cent each of phosphoric acid and potash, would be $1.08 a ton.

Greensand has fertilizing value and could be used in quantities of 5 to 40 tons an acre where it can be mined and applied at a cost closely related to its value. It does not contain sufficient fertilizer value to justify attempting to market it.

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THE FERTILIZING VALUE OF GREENSAND

G. S. FRAPS

Greensand is a green mineral having some fertilizing value, found in various parts of Texas, especially in the eastern part of the State and in the vicinity of San Antonio, and also in some eastern States of the United States, such as New Jersey, Maryland, and Virginia. The greensand in the eastern part of Texas is mixed with other materials to a considerable extent and is generally low in plant food but the deposits near San Antonio contain 3 to 5 per cent of total phosphoric acid and potash.

Greensand in the early part of the nineteenth century was extensively applied to soils in the eastern part of the United States, at the rate of 5 to 40 tons to the acre, or even as much as 200 tons, with good results. About 1850, when commercial fertilizers began to come into use, the use of greensand gradually decreased. The fertilizers furnished the plant food at less expense. Very little greensand is applied to soils at the present time. An extensive bibliography of greensand is given by Shreve (12).

The greensands in eastern Texas usually contain very low amounts of phosphoric acid and potash, and they have never been applied to soils to any appreciable extent. The greensand near San Antonio contains appreciable percentages of plant food and attempts have been made to market it as a fertilizer. The analyses and pot experiments reported in this Bulletin have been made in order to secure information regarding the composition of Texas greensand and the availability of its plant food to plants.

Deposits of greensand are not pure but contain larger or smaller amounts of greensand mixed with earth and sometimes with shells. Greensand is composed of dark, olive green to yellowish green grains, which are essentially grains of hydrous silicate of iron and potassium (glauconite) mixed with more or less silica. In some deposits, the iron has been oxidized to brown oxide of iron, but the deposit is usually of a greenish color.

Occurrence in Texas. There are extensive beds of greensand in the Cambrian formation in the Central Mineral Regions of Texas, and in the Upper Cretaceous, as well as in the upper part of the Taylor marl and in the Navarro beds (11). Greensand beds are frequent in the marine deposits of the Wilcox formation of the Eocene. Some of the counties in which these deposits are found will be named in connection with the discussion of their composition.

COMPOSITION OF GREENSAND

The New Jersey greensand contains .2 to 3 per cent of phosphoric acid and 1 to 6 per cent of potash, the better qualities containing 1 to 3 per cent of phosphoric acid and 5 to 6 per cent of potash. Analyses of samples from the eastern United States are given by True and Geise (15), Blair (2), and others. A compilation of 42 Texas analyses of greensand deposits made before 1917 is given by Dr. E. P. Schoch of the University of Texas (11). Other analyses of Texas samples are given in Table 1. Samples containing more than 3 per cent of phosphoric acid have been reported in Texas from Anderson county, Bexar county, and Rusk county. All of the other samples contain less than 1.9 per cent of phosphoric acid; samples from Anderson, Cass, Cherokee, Houston, Hunt, Kendall, Lee, Leon, Marion, Nacogdoches, Panola, Rusk, and San Augustine counties contained less than 0.5 per cent of phosphoric acid. Samples containing over 3 per cent of total potash were secured from Bexar, Cherokee, Kendall, Llano, Nacogdoches, and Rusk counties, but most of the samples contain less than 2 per cent of total potash. Samples from Anderson, Cass, Cherokee, Houston, Lee, Leon, Marion, Nacogdoches, Rusk, and San Augustine contained less than one per cent of potash.

The total potash given in Table 1 was estimated by the Lawrence Smith method of fusion with lime. The acid-soluble potash is that soluble in hydrochloric acid of 1.115 sp. gr., heated 10 hours in a boiling water bath. It is noted that practically all the potash is soluble in the strong hydrochloric acid. The potash soluble in water was estimated in a few of the samples and was found to be practically none at all, varying from .03 to 0.16 per cent. The iron and alumina, lime, and magnesia given in Table 1 were soluble in the same strong hydrochloric acid used for acid-soluble potash, and the insoluble was the inorganic material not dissolved by this solvent.

The samples examined contained 7.26 to 30.93 per cent of acid-soluble iron oxide and alumina, 0.9 to 12.42 per cent of acid-soluble lime, and 0.18 to 7.36 per cent of acid-soluble magnesia. Insoluble phosphoric acid, by the ammonium citrate method, in 6 of the samples was found to be nearly equal to the total phosphoric acid, so that the available phosphoric acid was practically negligible, varying from 0 to 0.43 per cent, with an average of 0.23 per cent. Acid-soluble manganese, in 4 samples, varied from .009 to .020 per cent, with an average of .015 per cent. These analyses show that when the phosphoric acid and potash are present in sufficient quantities to be of interest, the lime or manganese content is not large enough to justify the use of the material for the purpose of furnishing lime or manganese to soils which need one or the other.

Table 1.—Percentage composition of greensand.

Laboratory Number	County	Total phosphoric acid	Total Potash	Potash soluble in acid	Water-Soluble potash	Insoluble in acid	Iron and alumina oxides	Lime	Magnesia
4937	Anderson	.29	.....	.25	.....	.....	.....	.....	.....
9767	Hunt	.32	.....	.....	.....	18.22	7.26	38.14	1.00
11507	Rusk	.10	.....	.43	.....	54.82	29.60	.09	.68
16159	Kendall	.38	3.44	2.23	.....	68.02	19.77	2.42	.66
16160	Kendall	.32	2.18	1.92	.16	64.95	17.31	6.72	.23
16161	Kendall	.25	3.47	2.02	.09	69.20	18.84	.52	1.54
16366	Leon	.20	.....	.35	.....	30.68	34.85	.68	7.36
16371	Leon	.19	.76	.....	.16	.....	.....	.....	.....
16372	Leon	.04	.77	.....	.10	.....	.....	.....	.....
20187	Cherokee	.11	.54	.....	.....	.....	.....	.....	.....
24144	Bexar	5.04	2.12	.89	.03	44.03	30.40	6.62	2.20
29210	Bexar	5.70	4.24	4.23	.....	41.15	30.93	8.00	1.14
29220	Bexar	3.18	4.39	4.38	.03	48.75	27.27	5.35	1.84
29320	Bexar	4.39	4.71	4.44	.....	39.90	27.05	12.42	.18
29321	Bexar	2.82	4.51	4.20	.....	46.75	26.79	8.39	.44
29409	Bexar	4.97	5.05	5.00	.....	43.27	28.68	11.60	.52
29410	Bexar	6.30	4.75	4.70	.....	39.40	29.59	9.62	2.17
32277	Lee	.12	.....	.....	.....	.....	.....	.....	.....

VALUE TO PLANTS

The potash in greensand is chiefly combined with silica and is entirely insoluble in water. Greensand does not contain appreciable amounts of water-soluble potash such as is present in fertilizers. The phosphoric acid also is present as insoluble compounds. There is practically no available phosphoric acid such as is found in commercial fertilizers. The presence of 3 to 6 per cent of total phosphoric acid and 2 to 5 per cent of total potash in some samples of greensands naturally gives rise to the question of their value for fertilizing purposes, and the possibility of their utilization.

The greensand in New Jersey was usually applied at the rate of 10 to 40 tons an acre, but sometimes as little as 5 tons or as much as 200 tons was used. In these amounts, it had a favorable action on the soil, no doubt supplying some phosphoric acid and potash (1, 2, 15). Some varieties of greensand are acid and were found to be injurious unless the soil was limed or contained lime naturally (6, 15).

The chemical analysis shows the quantity of phosphoric acid and potash present in greensand but it does not show to what extent these fertilizing materials may be utilized by plants. This information regarding new materials can be ascertained by means of experiments on plants. Very few tests have been made of the capacity of plants to take total potash from greensand, and none have been found for the phosphoric acid. True and Geise (15) performed some pot experiments on wheat and clover with greensand from Virginia and New Jersey, applied at rates of 1 to 30 tons per acre, using the weight of the air-dried tops of the plants to measure the effect of the additions. The growth was not quite as good as with soluble potash salts, but the greensand supplied some potash. Skeen (13) compared greensand with nitrate of potash on wheat in pot experiments. The wheat grown on sand with the addition of 0.78 per cent of greensand (1.044 gms. K) secured 0.0125 grams of potassium from the greensand or about 1.1 per cent of the amount added. The wheat took up .0146 grams of potassium from 0.1103 grams of potassium applied as nitrate of potash or 13.2 per cent of the amount added. The maximum percentage of potash removed by the wheat from the greensand was 2.15 per cent of the quantity of potash added, which was removed from the pot containing 1 per cent of greensand or 1.392 grams of potassium (K). If the maximum percentage of potassium removed from the greensand (2.15 per cent) is divided by the percentage of potassium removed from the nitrate of potash (13.2 per cent), the availability of the potash in the greensand is found to be 16 per cent of that in the nitrate of potash.

POT EXPERIMENTS WITH GREENSAND

Pot experiments with plants are used to compare the relative amounts of plant food furnished by different materials. It is important that

the soil used in the pots be deficient in the element being studied, that deficiency in any other element be corrected by appropriate additions, and that the quantity of plant food added in the material being studied be less than the ability of the plant grown to take it up. It is also important to compare the amount of the plant food taken up by the plants as found by analysis and not the dry weights of the plants, for the reason that the weight of dry matter is not necessarily in proportion to the weight of nutrient absorbed. This is particularly true with potash (see Table 4), to a less extent with nitrogen, and still less with phosphoric acid, but even with phosphoric acid there may be decided variations in the phosphoric acid contained in the crop. Unless the plant food removed is considered, the conclusion from the experiment may be erroneous. The quantity taken from any material is ascertained by deducting the amount in the crop grown without the addition from the amount in the crop grown with it.

Experiments were conducted to test the availability to plants of potash and of phosphoric acid in greensand as compared with that in commercial fertilizers. Galvanized iron pots containing 5000 grams of soil were used. Each pot received additions of fertilizer containing the two forms of plant food not being studied. When the availability of the potash was being tested, each pot received additions of 1.0 gram of ammonium nitrate and 1.0 gram of dicalcium phosphate. When the availabity of phosphoric acid was being studied, the pots received additions of ammonium nitrate and sulphate of potash. The quartz sand 31116 received in addition 2.0 grams of sulphate of lime, 1.5 grams of magnesium sulphate, and 0.13 gm. of ferric chloride. Water was added to half the saturation capacity of the soil. Crops were planted as shown in the tables. The loss of water was replaced three times weekly. At the end of the period, the crop was cut near the roots, dried, weighed, and analyzed. In some cases a second crop was grown.

The samples used were ground samples of greensand from different deposits in Bexar county, and analyses of them are given in Table 1. Two portions of sample No. 29321 were used, one portion being ground ordinarily fine, the other very fine.

Details of the pot experiments are given in Tables 4 to 11, inclusive.

Series 99. Builders sand sample No. 29208 was used. It was reddish in color and contained some carbonate of lime. Dicalcium phosphate and ammonium nitrate were added to all the pots. Kafir was grown after the corn with no further addition of potash materials, to get the effect of a second crop. The results are recorded in Tables 4, 5, 8, and 9.

Series 104. Washed silica sand from the Ottawa Silica Company, sample No. 31116, was used with additions of calcium sulphate, magnesium sulphate, ferric chloride, dicalcium phosphate, and ammonium phosphate. Corn was grown. The results are recorded in Tables 6 and 10.

Series 108. Tabor fine sandy loam (surface soil) from Brazos county,

was used with additions of dicalcium phosphate and ammonium nitrate. Corn was grown. The results are recorded in Tables 7 and 11.

DISCUSSION OF RESULTS

Phosphoric acid. A summary of the results for phosphoric acid is given in Table 2. In soil No. 31170, the availability of the phosphoric acid of greensand compared with that of superphosphate varied from 14 to 40 per cent; in soil No. 29208, it varied from 0 to 34 per cent, in the first crop, and 0 to 19 per cent, for two crops, and in sand 31116 it was from 1 to 15 per cent. The phosphoric acid in sample No. 29220 had the highest availability. Taking all the results into consideration, an average availability of 10 per cent of that of superphosphate would be a liberal estimate for the availability of the phosphoric acid in greensand.

Table 2.—Comparative availability of phosphoric acid of greensand.

Soil Number		Per cent recovered of added phosphoric acid	Availability compared with super-phosphate as 100
31170 (corn)	Superphosphate	21.7	100
	Greensand 29210	8.7	40.0
	Greensand 29220	8.3	38.0
	Greensand 29320	3.0	14.0
31116	Superphosphate	15.4	100.0
	Greensand	1.2	8.0
	Greensand 29220	1.6	10.0
	Greensand 29320	0.7	5.0
	Greensand 29321	1.6	10.0
	Greensand 29409	2.3	15.0
	Greensand 29410	0.1	1.0
29208 (corn)	Superphosphate 33246	13.9	100.0
	Greensand 29210	.0	.0
	Greensand 29220	4.7	34.0
	Greensand 29320	.0	.0
	Greensand 29321	.0	.0
	Greensand 29321	.0	.0
	Greensand 29210	.0	.0
	Greensand 29409	.0	.0
	Greensand 29410	.0	.0
29208 (corn and kafir, 2 crops)	Superphosphate	30.3	100.0
	Greensand 29210	.0	.0
	Greensand 29220	5.8	19.0
	Greensand 29320	.0	.0
	Greensand 29321	1.2	4.0
	Greensand 29321	.0	.0
	Greensand 29409	0.6	.2
	Greensand 29410	.0	.0

Variations in the recovery of phosphoric acid from rock phosphate, similar to those named above, have already been observed (3). In 21 experiments, the phosphoric acid of rock phosphate averaged 21 per cent of the availability of that of superphosphate, though it varied from 0 to 45 per cent.

Potash. A summary of the results with potash is given in Table 3. The amount of potash removed from the greensand, compared with that

from muriate of potash as 100, is 4.5 to 9.5 with soil No. 31170, 0 to 9.5 with the first crop on soil No. 29208, 0 to 12.4 for the two crops on soil No. 29208, and 0.4 to 1.1 on soil No. 31116. Taking all the results into consideration, an availability of 8 per cent of that of muriate of potash would be a liberal estimate for the availability of potash in greensand. The potash taken up varies to a less extent than the phosphoric acid.

Table 3.—Comparative availability of potash of greensand.

Soil Number		Per cent recovered of potash added	Relative availability (potash in muriate or as sulphate 100)
31170 (corn)	Muriate of potash	79.8	100
	Greensand 29210	7.6	9.5
	Greensand 29220	3.6	4.5
31116 (corn)	Muriate of potash (0.5 gm.)	75.6	100
	Muriate of potash (1.0 gm.)	68.9	.....
	Greensand 29210	0.8	1.1
	Greensand 29220	0.4	.5
	Greensand 29320	0.4	.5
	Greensand 29321	0.3	.4
	Greensand 29409	0.4	.5
	Greensand 29410	0.6	.8
29208 (corn)	Muriate of potash	77.9	100
	Greensand 29210	6.4	8.2
	Greensand 29220	7.3	9.5
	Greensand 29320	4.6	5.9
	Greensand 29321	6.1	7.8
	Greensand 29321 (50 gm.)	1.5	1.9
	Greensand 29210	.0	.0
	Greensand 29331	4.0	.51
	Greensand 29409	.0	.0
	Greensand 29410	0.8	1.0
29208 (2 crops, corn and kafir)	Muriate of potash	91.9	100
	Greensand 29210	10.8	11.8
	Greensand 29220	11.4	12.4
	Greensand 29320	4.6	5.0
	Greensand 29321	6.1	6.6
	Greensand 29321 (50 gm.)	1.5	1.6
	Greensand 29210	0.	.0
	Greensand 29331	4.0	4.4
	Greensand 29409	.0	.0
	Greensand 29410	0.8	0.9

The potash removed may be compared with that removed from other minerals. Fraps (4) by means of pot experiments found that, with the potash removed from sulphate of potash as 100, the comparative percentage removed from finely ground microcline and orthoclase was 2 to 10 per cent, from muscovite 25 to 30 per cent, from biotite about 35 per cent, and from nephelite about 20 per cent. The potash in greensand is not taken up as readily as that in biotite or muscovite, which are varieties of mica.

High quantities of greensand. The effect of larger amounts of greensand was tried in several experiments. On soil No. 29208 (Table 4) increasing the greensand 5 times increased the potash taken out only about one-sixth, and the amount removed was much lower than from

less than one-fourth as much potash in muriate of potash. The second crop (Table 5) recovered practically no potash from this large addition.

Only small amounts of phosphoric acid were removed from 50 grams of greensand alone (Tables 8 and 9), or supplemented by nitrogen, although the nitrogen increased the amount of phosphoric acid taken up.

Value of greensand. A fertilizer containing 5 per cent each of available phosphoric acid and water-soluble potash, at the prevailing valuations (5) of 6 cents a pound for each, would have a fertilizer valuation of $12.00 a ton. With the maximum availability found in these experiments of 40 per cent for phosphoric acid and 12 per cent for potash, the value of a greensand containing 5 per cent of total phosphoric acid and 5 per cent of total potash, compared with the commercial fertilizer, would be $3.12 a ton. If instead of the maximum availability for greensand, there is used the liberal estimate of 10 per cent availability of phosphoric acid and 8 per cent availability for potash, the comparative value of the greensand mentioned above would be $1.08 a ton. Greensand containing less phosphoric acid and potash would of course have a lower value.

The use of greensand at the rate of 10 to 40 tons per acre would no doubt supply some phosphoric acid and potash to the soil and so increase the growth of crops on soils which need phosphoric acid and potash. Greensand could be utilized when it could be mined and applied at a low cost. The fertilizing value is too low for commercial sale in comparison with ordinary commercial fertilizers.

Other uses. Attempts have been made to use greensand for the manufacture of potash salts, and it is also used as a water softener (12).

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Pot	Potash addition	Potash in addition	Dry crop, grams	Potash in crop, per cent	Potash in crop	DNG_{12}	Recovered
28 DNKa	1 gm. muriate of potash 33353	.5007	13.4	3.64	.4878		
29 DNKa			13.5	3.84	.5184		
30 DNKa			12.0	3.67	.4404		
Average			13.0	3.72	.4822	.3898	77.9
31 DNG_5	10.0 gm. greensand 29210	.424	12.1	1.06	.1283		
32 DNG_5			11.9	.93	.1107		
33 DNG_5			13.2	.91	.1201		
Average			12.4	.97	.1197	.0273	6.4
34 DNG_6	10.0 gm. greensand 29220	.440	12.3	1.07	.1316		
35 DNG_6			12.8	.94	.1203		
36 DNG_6			12.8	.95	.1216		
Average			12.6	.99	.1245	.0321	7.3
37 DNG_7	10.0 gm. greensand 29320	.471	10.4	.83	.0863		
38 DNG_7			17.5	.87	.1523		
39 DNG_7			11.7	.89	.1041		
Average			13.2	.86	.1142	.0218	4.6
40 DNG_8	10.0 gm. greensand 29321	.451	13.7	.97	.1329		
41 DNG_8			11.0	1.03	.1133		
42 DNG_8			12.7	.89	.1130		
Average			12.5	.96	.1197	.0273	6.1
43 DN_5G_8	50.0 gm. greensand 29321	2.255	12.7	.99	.1257		
44 DN_5G_8			15.9	.94	.1495		
45 DN_5G_8			9.4	1.11	.1043		
Average			12.7	1.01	.1265	.0341	1.5
46 DNGR	10 gm. greensand 29321 (finely ground)	.451	.92	1.00	.0920		
47 DNGR			8.2	1.34	.1099		
48 DNGR			13.5	.96	.1296		
Average			10.3	1.10	.1105	.0181	4.0
62 DNG_{12}	10.0 gm. greensand 29409	.0475	9.5	.83	.0789		
63 DNG_{12}			10.7	.99	.1059		
Average			10.1	.91	.0924		
64 DNG_{13}	10 gm. greensand 29410	.505	11.2	.83	.0930		
65 DNG_{13}			11.5	.88	.1012		
66 DNG_{13}			7.5	1.27	.0953		
Average			10.1	.99	.0965	.0041	0.8

Table 5.—Details of second crop of kafir on soil No. 29208, for potash.

Pot	Potash addition	Grams potash in addition	Weight crop, grams	Potash in crop, per cent	Grams potash in crop	Gain over DNG_{12}	Per cent recovered
28 DNKa	1.0 gm. muriate of potash 33353	.5007	18.9	.90	.1701		
29 DNKa			16.0	.99	.1584		
30 DNKa			12.2	1.26	.1537		
Average			15.7	1.05	.1607	.0703	14.0
31 DNG_5	10.0 gm. greensand 29210	.424	11.5	.79	.0909		
32 DNG_5			17.5	.72	.1260		
33 DNG_5			16.3	.68	.1108		
Average			15.1	.73	.1092	.0188	4.4
34 DNG_6	10.0 gm. greensand 29220	.440	16.2	.67	.1085		
35 DNG_6			12.8	.82	.1050		
36 DNG_6			17.6	.61	.1074		
Average			15.5	.70	.1070	.0166	3.8
37 DNG_7	10.0 gm. greensand 29320	.471	6.8	1.22	.0830		
38 DNG_7			12.6	.75	.0945		
39 DNG_7			11.1	.74	.0821		
Average			10.2	.90	.0865	.0	.0
40 DNG_8	10.0 gm. greensand 29321	.451					
41 DNG_8			12.7	.53	.0673		
42 DNG_8			12.7	.61	.0775		
Average			12.7	.57	.0724	.0	.0
43 DN_8G_8	50 gm. greensand 29321	2.255	2.6	1.73	.0450		
44 DN_8G_8			15.4	.70	.1078		
45 DN_8G_8			5.3	1.34	.0710		
Average			7.8	1.26	.0746	.0	.0
46 DNGR	10 gm. greensand 29321 (finely ground)	.424	9.1	.78	.0710		
47 DNGR			11.3	.65	.0735		
48 DNGR			13.1	.96	.1258		
Average			11.2	.80	.0901	.0	.0
49 G_9	50 gm. greensand 29321	2.255	2.0	1.57	.0314		
50 G_9			2.1	1.49	.0313		
51 G_9			2.1	1.32	.0277		
Average			2.1	1.46	.0301	.0	.0

52 NG_9	50 gm. greensand 29321	2.255	10.3	.95	.0979		
53 NG_9			4.5	1.96	.0882		
54 NG_9			4.4	1.71	.0752		
Average			6.4	1.54	.0871	.0	.0
61 DNG_{12}	10 gm. greensand 29409	.505	14.2	.69	.0980		
62 DNG_{12}			9.2	.80	.0736		
63 DNG_{12}			11.7	.85	.0995		
Average			11.7	.78	.0904		
64 DNG_{13}	10 gm. greensand 29410	.475	13.1	.77	.1009		
65 DNG_{13}			10.0	.66	.0660		
66 DNG_{13}			9.3	.74	.0688		
Average			10.8	.72	.0786	.0	.0

Table 6.—Details of experiments with corn on soil No. 31116, Series 104, for potash.

Pot	Potash addition	Grams potash in addition	Weight crop, grams	Potash in crop, per cent	Grams potash in crop	Gain over DN	Per cent recovered
28 DN	None	.0	0.1	.56	.0006		
29 DN			Less than 0.1	.56	.0006		
30 DN			Less than 0.1	.56	.0006		
Average			.1	.56	.0006		
31 DNKa	0.5 gm. muriate of potash 34157	.255	10.0	2.02	.2020		
32 DNKa			10.5	1.74	.1827		
33 DNKa			10.5	1.85	.1943		
Average			10.3	1.87	.1930	.1924	75.6
34 DN_2Ka	1.0 gm. muriate of potash 34157	.509	8.5	4.40	.3740		
35 DN_2Ka			12.0	2.84	.3408		
36 DN_2Ka			8.7	3.89	.3384		
Average			9.7	3.71	.3511	.3505	68.9
37 DNG_7	10 gm. greensand 29210	.424	1.0	.56	.0056		
38 DNG_7			0.6	.56	.0034		
39 DNG_7			0.6	.56	.0034		
Average			0.7	.56	.0041	.0035	0.8

Table 6.—Details of experiments with corn on soil No. 31116, Series 104, for potash—Continued.

Pot	Potash addition	Grams potash in addition	Weight crop, grams	Potash in crop, per cent	Grams potash in crop	Gain over DN	Per cent recovered
40 DNG_8	10 gm. greensand 29220	.440	.7	.42	.0029		
41 DNG_8			0.1	.42	.0004		
42 DNG_8			1.0	.42	.0042		
Average			0.6	.42	.0025	.0019	0.4
43 DNG_9	10 gm. greensand 29320	.471	Less than 0.1	.63	.0006		
44 DNG_9			0.5	.63	.0032		
45 DNG_9			0.5	.63	.0032		
Average			.4	.63	.0023	.0017	0.4
46 DNG_{10}	10 gm. greensand 29321	.451	Less than 0.1	.56	.0006		
47 DNG_{10}			.8	.56	.0045		
48 DNG_{10}			0.1	.56	.0006		
Average			.3	.56	.0019	.0013	0.3
49 DNG_{11}	10 gm. greensand 29409	.505	.3	.50	.0015		
50 DNG_{11}			Less than 0.1	.50	.0005		
51 DNG_{11}			1.3	.50	.0065		
Average			.6	.50	.0028	.0022	0.4
52 DNG_{12}	10 gm. greensand 29410	.475	1.0	.52	.0052		
53 DNG_{12}			.4	.52	.0021		
54 DNG_{12}			.6	.52	.0031		
Average			.7	.52	.0035	.0029	0.6

Table 7.—Experiments with corn, soil No. 31170, Series 108, for potash.

Pot	Potash addition	Grams potash in addition	Weight crop, grams	Potash in crop, per cent	Grams potash in crop	Gain over DN	Per cent recovered
19 DN	None	.0	19.5	2.05	.3998		
20 DN			12.6	2.51	.3163		
21 DN			12.2	2.53	.3087		
Average			14.8	2.36	.3416		
22 DNKa	0.5 gm. muriate of potash	.2545	16.9	3.17	.5357		
23 DNKa			23.0	2.44	.5612		
24 DNKa			21.4	2.51	.5371		
Average			20.4	2.71	.5447	.2031	79.8
25 DNG$_7$	10 gm. greensand 29210	.424	21.3	1.82	.3877		
26 DNG$_7$			17.1	2.27	.3882		
27 DNG$_7$			15.1	2.29	.3458		
Average			17.8	2.13	.3739	.0323	7.6
28 DNG$_8$	10 gm. greensand 29220	.440	19.2	1.82	.3494		
29 DNG$_8$			20.2	1.95	.3939		
30 DNG$_8$			14.5	2.27	.3292		
Average			18.0	2.01	.3575	.0159	3.6

Table 8—Experiment with corn for phosphoric acid, soil No. 29208, Series 99.

Marks	Phosphate addition	Grams phosphoric acid in addition	Weight, crop, grams	Phosphoric acid in crop, per cent	Grams phosphoric acid in crop	Gain over KN	Per cent recovered
1 KN		.0	11.2	.20	.0224		
2 KN			10.8	.23	.0248		
3 KN			11.8	.21	.0248		
Average			11.3	.21	.0240		
4 KNP	0.5 gm. superphosphate No. 33246	.0852	14.8	.22	.0326		
5 KNP			13.0	.25	.0325		
6 KNP			24.9	.17	.0423		
Average			17.6	.21	.0358	.0118	13.9
7 KNG_1	2.0 gm. greensand No. 29210	.1140	9.2	.23	.0212		
8 KNG_1			6.8	.21	.0143		
9 KNG_1			15.6	.20	.0312		
Average			10.5	.21	.0222	.0	.0
10 KNG_2	2.0 gm. greensand No. 29220	.0636	14.4	.20	.0288		
11 KNG_2			12.5	.22	.0275		
12 KNG_2			14.5	.17	.0247		
Average			13.8	.20	.0270	.0030	6.8
13 KNG_3	2.0 gm. greensand No. 29320	.0878	9.7	.16	.0155		
14 KNG_3			9.5	.21	.0200		
15 KNG_3			11.5	.19	.0219		
Average			10.2	.19	.0191	.0	.0
16 KNG_4	2.0 gm. greensand No. 29321	.0564	8.8	.21	.0185		
17 KNG_4			9.9	.17	.0168		
18 KNG_4			14.1	.18	.0254		
Average			10.9	.19	.0202	.0	.0
19 KN_5G_4	10.0 gm. greensand No. 29321	.2820	6.2	.27	.0167		
20 KN_5G_4			6.6	.22	.0145		
21 KN_5G_4			9.6	.17	.0163		
Average			7.5	.22	.0158	.0	0

25 KGNF	2.0 gm. greensand No. 29210, finally ground	.1140	8.6	.21	.0181		
26 KNGF			12.8	.19	.0243		
27 KNGF			14.3	.21	.0300		
Average			11.9	.20	.0241	.0001	.0
49 G_9	50 gm. greensand No. 29321	1.4100	3.2	.25	.0080		
50 G_9			3.3	.26	.0086		
51 G_9			3.1	.22	.0068		
Average			3.2	.24	.0078		
52 NG_9	50 gm. greensand No. 29321	1.410	9.8	.27	.0265		
53 NG_9			8.7	.21	.0183		
54 NG_9			9.5	.24	.0228		
Average			9.3	.24	.0225	.0	.0
55 KNG_{10}	2.0 gm. greensand No. 29409	.0994	7.0	.20	.0140		
56 KNG_{10}			7.5	.19	.0143		
57 KNG_{10}			11.5	.17	.0196		
Average			8.7	.19	.0160	.0	.0
58 KNG_{11}	2.0 gm. greensand No. 29410	.1260	7.5	.20	.0150		
59 KNG_{11}			7.5	.25	.0188		
60 KNG_{11}			6.0	.22	.0132		
Average			7.0	.22	.0157	.0	.0

Table 9.—Experiment with kafir, following corn, soil No. 29208, Series 99.

Marks	Phosphate addition	Grams phosphoric acid in addition	Weight, crop, grams	Phosphoric acid in crop, per cent	Grams phosphoric acid in crop	Gain over KN	Per cent recovered
1 KN		.0	9.7	.17	.0165		
2 KN			10.7	.14	.0150		
3 KN			10.5	.16	.0168		
Average			10.3	.16	.0161		
4 KNP	0.5 gm. superphosphate No. 33246						
5 KNP							
6 KNP							
Average			7.0	.43	.0301		
7 KNG_1	2.0 gm. greensand No. 29210	.1140	7.0	.43	.0301	.0140	16.4
8 KNG_1			7.2	.16	.0115		
9 KNG_1			9.5	.14	.0133		
Average			8.5	.24	.0204		
10 KNG_2	2.0 gm. greensand No. 29220	.0636	8.4	.18	.0151	.0	.0
11 KNG_2			7.2	.20	.0144		
12 KNG_2			15.2	.13	.0198		
Average			10.7	.15	.0161		
13 KNG_3	2.0 gm. greensand No. 29320	.0878	11.0	.16	.0168	.0007	1.1
14 KNG_3			10.8	.16	.0173		
15 KNG_3			10.2	.15	.0153		
Average			9.7	.14	.0136		
16 KNG_4	2.0 gm. greensand No. 29321	.0564	10.2	.15	.0154	.0	.0
17 KNG_4			14.2	.14	.0199		
18 KNG_4			11.0	.13	.0143		
Average			11.5	.14	.0161		
19 KN_5G_4	10.0 gm. greensand No. 29321	.564	12.2	.14	.0168	.0007	1.2
20 KN_5G_4			8.3	.17	.0141		
21 KN_5G_4			11.8	.13	.0153		
Average			11.8	.14	.0165		
			10.6	.15	.0153	.0	.0

25 KNGF	2.0 gm. greensand No. 29210, finely ground.	.1140	6.3	.14	.0088		
26 KNGF			16.4	.16	.0262		
27 KNGF			10.8	.14	.0151		
Average			11.2	.15	.0167	.007	0.6
55 KNG_{10}	2.0 gm. greensand No. 29409	.0994	8.8	.14	.0123		
56 KNG_{10}			8.8	.15	.0132		
57 KNG_{10}			11.7	.15	.0176		
Average			9.8	.15	.0144	.0	.0
58 KNG_{11}	2.0 gm. greensand No. 29410	.1260	11.5	.14	.0161		
59 KNG_{11}			9.2	.16	.0147		
60 KNG_{11}			10.0	.14	.0140		
Average			10.2	.15	.0149	.0	.0

Table 10—Experiment with corn, Soil No. 31116, Series 104, for phosphoric acid.

Marks	Phosphate addition	Grams phosphoric acid in addition	Weight, crop, grams	Phosphoric acid in crop, per cent	Grams phosphoric acid in crop	Gain over KN	Per cent recovered
1 NK			1.0	.27	.0027		
2 NK			2.5	.19	.0048		
3 NK			0.3	.19	.0006		
Average			1.3	.22	.0027		
4 NKP	0.5 gm. superphosphate No. 34016	.0814	5.0	.29	.0145		
5 NKP			7.2	.27	.0194		
6 NKP			4.0	.29	.0116		
Average			5.4	.28	.0152	.0125	15.4
7 NKG_1	2 gm. greensand No. 29210	.1140	1.9	.26	.0049		
8 NKG_1			1.4	.20	.0028		
9 NKG_1			2.5	.18	.0045		
Average			1.9	.21	.0041	.0014	1.2
10 NKG_2	2 gm. greensand No. 29220	.0636	1.7	.20	.0034		
11 KNG_2			2.1	.21	.0044		
12 KNG_2			1.5	.22	.0033		
Average			1.8	.21	.0037	.0010	1.6

Table 10.—Experiment with corn, soil No. 31116, Series 104, for phosphoric acid—Continued.

Marks	Phosphate addition	Grams phosphoric acid in addition	Weight, crop, grams	Phosphoric acid in crop, per cent	Grams phosphoric acid in crop	Gain over KN	Per cent recovered
13 NKG_3	2 gm. greensand No. 29320	.0878	2.5	.21	.0053		
14 NKG_3			1.1	.20	.0022		
15 NKG_3			1.1	.22	.0024		
Average			1.6	.21	.0033	.0006	0.7
16 NKG_4	2 gm. greensand No. 29321	.0564	2.3	.22	.0051		
17 NKG_4			1.5	.19	.0029		
18 NKG_4			1.5	.19	.0029		
Average			1.8	.20	.0036	.0009	1.6
19 NKG_5	2 gm. greensand No. 29409	.0994	2.2	.23	.0051		
20 NKG_5			3.0	.18	.0054		
21 NKG_5			2.1	.22	.0046		
Average			2.4	.21	.0050	.0023	2.3
22 NKG_6	2 gm. greensand No. 29410	.1260	0.8	.22	.0018		
23 NKG_6			1.1	.19	.0021		
24 NKG_6			2.2	.20	.0044		
Average			1.4	.20	.0028	.0001	0.1
25 NK_2P	1.0 gm. superphosphate No. 34016	.1628	10.7	.31	.0332		
26 NK_2P			12.7	.25	.0318		
27 NK_2P			14.0	.26	.0364		
Average			12.5	.27	.0338	.0311	19.1

Table 11—Experiment with corn, soil No. 31170, Series 108, for phosphoric acid.

Marks	Phosphate addition	Grams phosphoric acid in addition	Weight, crop, grams	Phosphoric acid in crop, per cent	Grams phosphoric acid in crop	Gain over KN	Per cent recovered
1 NK		0	13.3	.32	.0426		
2 NK			13.5	.33	.0446		
3 NK			15.5	.33	.0512		
Average			14.1	.33	.0461		
4 NKP	0.5 gm. superphosphate	.0814	16.0	.39	.0624		
5 NKP			17.1	.37	.0633		
6 NKP			16.0	.41	.0656		
Average			16.4	.39	.0638	.0177	21.7
7 NKG_1	2 gm. greensand No. 29210	.1140	12.5	.38	.0475		
8 NKG_1			15.5	.39	.0605		
9 NKG_1			17.0	.35	.0595		
Average			15.0	.37	.0558	.0097	8.7
10 NKG_2	2 gm. greensand No. 29220	.0636	15.1	.34	.0513		
11 NKG_2			10.0	.34	.0340		
12 NKG_2			13.6	.38	.0517		
Average			12.9	.35	.0457	.00	8.3
13 NKG_3	2 gm. greensand No. 29320	.0878	13.6	.37	.0503		
14 NKG_3			2.4	.38	.0091		
15 NKG_3			13.4	.35	.0469		
Average			9.8	.37	.0354	.00	3.0
16 NK_2P	1 gm. superphosphate	.1627	16.8	.43	.0722		
17 NK_2P			15.3	.47	.0719		
18 NK_2P			17.0	.39	.0663		
Average			16.4	.43	.0701	.0240	14.8

SUMMARY

Greensand is a mineral containing phosphoric acid and potash extensively distributed through Texas. Some greensand deposits containing 3 to 6 per cent of phosphoric acid have been reported as occurring in Anderson, Bexar, and Rusk counties, while deposits containing 3 to 6 per cent of total potash have been found in Bexar, Cherokee, Kendall, Llano, Nacogdoches, and Rusk counties. Deposits occur in East Texas, but generally contain only small percentages of phosphoric acid and potash.

Greensand was formerly extensively applied to soils in the eastern part of the United States at the rate of 5 to 40 tons to the acre, with good results, but it is little used at the present time.

The potash in greensand is not soluble in water, as is the case with commercial fertilizers, but is almost completely soluble in strong acids. The phosphoric acid is not available, like that in commercial fertilizers, but is also soluble in acids.

Pot experiments on three soils were made for the purpose of ascertaining the availability to plants of the phosphoric acid and potash of greensand. The availabity was measured by the quantities of phosphoric acid and potash removed by corn or kafir, from several samples of greensand, in excess of the quantity removed from the soils compared with the amounts of potash removed from muriate or sulphate of potash or the phosphoric acid removed from superphosphate, under the same conditions.

The maximum availability of the phosphoric acid in greensand was 40 per cent of that of superphosphate, while the minimum was zero. The maximum availability of the potash of greensand compared with that of potash salts was 12 per cent. A liberal average availability was 10 per cent for phosphoric acid and 8 per cent for potash in greensand.

The value of greensand containing 5 per cent each of phosphoric acid and potash, compared with a commercial fertilizer of the same composition which would have a valuation of $12.00 a ton at the present time, would be $3.12 a ton if the maximum availability of the potash and phosphoric acid in greensand is used. If the availability of 10 per cent for phosphoric acid and 8 per cent for potash is used, the comparative value of greensand containing 5 per cent each of phosphoric acid and potash, would be $1.08 a ton.

Greensand has fertilizing value and could be used in quantities of 5 to 40 tons an acre where it can be mined and applied at a cost closely related to its value. It does not contain sufficient fertilizing value to justify attempting to sell it as a commercial fertilizer.

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