Sulfur Content

of Oklahoma Soils, Rainfall and Atmosphere

OKLAHOMA STATE UNIVERSITY
SCIENCE SERVING AGRICULTURE
1891
EXPERIMENT STATION

by
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Bulletin B-536
November 1959

CONTENTS

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Many high analysis fertilizers now being manufactured contain little or no sulfate. Several experiments (3, 5, 7, 8) in different states show that on some soils sulfur must be used with these fertilizers to produce maximum crop yields.

This publication summarizes the available information on the amounts of sulfur in Oklahoma soils and on the amounts of atmospheric sulfur deposited by rainfall.

Sulfur and Nitrogen in Virgin and Cropped Soils

Table 1 shows sulfur content, nitrogen content, and nitrogen-sulfur ratio for 170 paired samples of surface soil from virgin areas and adjacent areas in cultivation.[1] These data show that the sulfur content of a high percentage of the cultivated soils was very low. Seventy percent of the samples contained .015 percent or less of total sulfur. However, some of the cultivated soils contained as much total sulfur as adjacent virgin areas; and in a few cases the total sulfur content was higher in the sample from the cultivated area. Loss of sulfur as a result of cultivation averaged about 30 percent, as compared to a nitrogen loss of 37 percent.

The nitrogen-sulfur ratio was quite variable. Soils high in nitrogen normally were also higher in total sulfur, but there was no close correlation in either virgin or cropped soils. Slightly more than half (55 percent) of the cropped soils had a narrower nitrogen-sulfur ratio than the corresponding virgin soil. The average ratio on a percentage basis was 7.5 to 1 for the virgin soils and 7.6 to 1 for the cropped soils.[2]

In Kansas, Swanson and Latshaw (6) found a ratio of 5.5 to 1 in both virgin soils and soils cropped to grain in the humid portion of that state, for 10 sets of paired samples. Nine pairs from the subhumid area

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[1] The method of analysis used for determining total sulfur in soil is described in the appendix.

[2] The average nitrogen-sulfur ratio on a molecular basis would be about 16.9 to 1 in the virgin soils and 17.2 to 1 in the cropped soils.

had average ratios of 6.6 to 1 in virgin soils and 3.8 to 1 in cropped soils; and for 10 pairs from the semiarid portion of western Kansas the respective ratios were 5.3 to 1 and 4.8 to 1. Soils that produced alfalfa for several years contained more sulfur than virgin soils in the subhumid and semiarid part of that state.

It is unlikely that the sulfur content of cropped soils represented in Table 1 has been affected by fertilization. In a wheat experiment at Stillwater, the application of barnyard manure at an average rate of 3.5 tons per acre annually over a 40 year period increased the sulfur content of the soil about sixty pounds per acre as compared to an adjacent unmanured plot. However, use of barnyard manure is uncommon in Oklahoma, and the residual effect of sulfur-containing mineral fertilizers, had they been used, would have been greatly reduced by leaching in the central and eastern part of the state.

Sulfur, Nitrogen, and Phosphorus Relationships in 18 Soil Profiles

Table 2 shows the total sulfur, nitrogen and phosphorus contents, and the nitrogen-sulfur and phosphorus-sulfur ratios, of 18 soil profiles representing 12 soil series. In general, it would be assumed that the ratios at different depths in a soil profile reflect the different factors which affect the accumulation and decomposition of organic matter, since the organic matter in surface soil contains practically all of the nitrogen and about one-third of the phosphorus.

Nitrogen-Sulfur Ratios

In 12 of the soil profiles, the nitrogen-sulfur ratios in the different horizons were relatively constant within each profile. In 6, they became narrower with increasing depth.

The average nitrogen-sulfur ratio for the surface layers of the 18 profiles was 7.3 to 1. The narrowest was 3.86 to 1 in San Saba clay, which was very high in both total sulfur and total nitrogen. The widest was 11 to 1 in Durant fine sandy loam from Choctaw county.

The extremely narrow ratios in the two lowest horizons of the Tillman clay loam from Kiowa county are due to the presence of inorganic sulfates which were not carried into the deeper subsoil by percolating water during the process of soil formation. This condition is frequently observable in the lower part of the profile of many lime-accumulating soils in western Oklahoma, and also may be seen in the profile of some poorly drained soils in the central and eastern part of the state. These accumulations appear during dry weather as crystals in the soil or as a white powder on the face of exposed sections of a profile, and usually are located a few inches below the zone of maximum lime accumulation in semiarid and arid regions.

Phosphorus-Sulfur Ratios

The phosphorus-sulfur ratios were usually narrowest in the surface layers. The average ratio in the surface layer was 1.7 to 1. The narrowest, 0.55 to 1, was in the San Saba clay from Choctaw county; and the widest, 6.6 to 1, was in the Durant fine sandy loam from Murray county.

The decrease of total sulfur from the surface downward was more rapid than the decrease of total phosphorus in 9 of the 18 profiles.

Inorganic Sulfur in 11 Soil Profiles

Table 3 presents results of a study of the quantity of water soluble inorganic sulfur in different portions of 11 soil profiles in northern Oklahoma. The 11 profiles represent 7 soil series. Each profile was sampled at one-foot intervals from the surface downward to a depth of 7 feet.

A small quantity of sulfate sulfur was present in every soil layer sampled. The lowest concentrations occurred in soils with sandy subsoils. Only two of the profiles (nos. 3 and 7) were sufficiently impervious to prevent soluble sulfates from being carried downward to a depth greater than 7 feet.

Several locations have been observed in central and eastern Oklahoma where a crystalline form of gypsum (selenite), can be found in the subsoils of poorly drained soil profiles, sometimes at a depth of less than four feet. All of the upland soils in which these crystals are found, such as the Parsons and Cherokee series, contain impervious clay layers which prevent the downward movement of percolating water. The sulfur in these soils probably originated from the oxidation of iron pyrite occurring in the shales on which soil development occurred. Selenite crystals also may be found occasionally in the subsoils of Lightning and Atkins clay loam which are soil types with poor internal drainage occurring in the flood plain of some stream valleys where a high percentage of the alluvium was derived from weathered sulfate-containing shale.

Sulfur Content of Oklahoma Rainfall

Table 4 presents data obtained in a study of the amount of sulfur in annual rainfall. From these data, it is estimated that the total sulfur in rainfall, in pounds per acre per year, was about 6 pounds in western Oklahoma, 8 to 12 pounds in central Oklahoma, and about 17 pounds in eastern Oklahoma. These quantities are much lower than in areas where more coal is used as fuel (2).

The concentration of sulfur in rainfall at Stillwater was highest during October, November and December, when rainfall was relatively low. However, the most sulfur brought down by rainfall during a three-month period was during April, May and June when rainfall was most abundant. The concentration of sulfur in the rain at Goodwell was almost twice that at Stillwater.

The average sulfur content per acre inch of rainfall at Stillwater was similar to that reported for other areas of limited industrial development.

Sulfur in the Atmosphere

Table 5 compares the quantities of sulfur in the atmosphere at Stillwater and at two sites in Minnesota in 1941-42. Quantities were determined by exposing lead peroxide coated fabric to the atmosphere and analyzing for the sulfur absorbed as sulfur dioxide. The fabrics were exposed on cylinders placed four feet above the ground on the Agronomy Farm at Stillwater, on the University Farm at St. Paul, Minn., and in open country one mile from Bemidiji, Minn.[3]

It is quite evident that the qantity of sulfur dioxide in the air in the two rural areas as shown in Table 6 was much lower than in air adjacent to a large city. Soil absorbed only 22 percent as much sulfur dioxide from the air as was absorbed on an equivalent area of lead peroxide coated fabric located 4 feet above the ground. Pincus and Stern (4) estimated that two thousand tons of sulfur dioxide is discharged into the air of New York City every day.

Summary

Data are reported on: (1) Sulfur and nitrogen in 170 paired samples of virgin and adjacent cultivated soils; (2) sulfur, nitrogen and phosphorus in 18 soil profiles; (3) inorganic sulfur in 11 soil profiles to a depth of 7 feet; (4) atmospheric sulfur deposited by rainfall at Stillwater, Okla., during the 15-year period 1927-42 (excepting 1940), and at other Oklahoma locations for lesser periods; and (5) atmospheric sulfur content at Stillwater and at two locations in Minnesota during a 12-month period in 1941-42.

(1) Average nitrogen-sulfur ratio was 7.5 to 1 in the virgin soils and 7.6 to 1 in the cultivated soils. Average loss as a result of cultivation was about 30 percent for sulfur and about 37 percent for nitrogen.

(2) Average nitrogen-sulfur ratio in the surface layers of 18 profiles was 7.3 to 1. The narrowest was 3.86 to 1 in a San Saba clay sample and the widest 11 to 1 in a Durant fine sandy loam sample. The ratios were either relatively constant in the different layers, or decreased in the lower parts of the profiles. In half of the profiles, total sulfur decreased more rapidly with depth than did total phosphorus.

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[3] This study was supervised by Dr. F. J. Alway, Department of Soils, University of Minnesota, St. Paul, Minnesota.

Average phosphorus-sulfur ratio in the surface layers was 1.7 to 1. The San Saba clay had the narrowest ratio of 0.5 to 1; and the Durant fine sandy loam had the widest, 6.6 to 1.

(3) Two of the profiles contained much higher concentrations of sulfate sulfur than did the other nine. Downward movement of water was restricted by a subsurface layer of impervious clay in these profiles.

(4) Average sulfur content of rainfall at Stillwater was 8.7 pounds per acre per year. At other locations the annual quantity varied from about 6 to 18 pounds per acre.

(5) Atmospheric sulfur at Stillwater, Oklahoma was less than 4 percent of that present at St. Paul, Minn. and was comparable to that at Bemidiji, Minn. Sulfur dioxide was absorbed on the surface of a lead peroxide coated fabric in this study.

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Table 1.—Sulfur and Nitrogen Content and the Nitrogen-Sulphur ratio of 170 Paired Samples of Virgin and Cultivated Surface Soils Collected from 58 Counties in Oklahoma.

County and Soil Number	Sulfur in Percent Virgin	Sulfur in Percent Cropped	Nitrogen in Percent Virgin	Nitrogen in Percent Cropped	Nitrogen-Sulfur Ratio Virgin	Nitrogen-Sulfur Ratio Cropped
Alfalfa						
219-220	.010	.010	.072	.052	7.2	5.2
4192-94	.019	.011	.144	.106	7.6	9.6
4196-98	.025	.012	.146	.098	5.8	8.2
4200-02	.015	.010	.144	.050	9.6	5.0
Atoka						
1289-90	.026	.016	.218	.084	8.4	5.3
Blaine						
1585-86	.019	.011	.064	.061	4.9	5.6
1609-10	.029	.011	.127	.047	4.4	4.3
Bryan						
335-36	.014	.014	.114	.091	8.1	6.5
Caddo						
187-88	.012	.011	.064	.071	5.3	6.5
1549-50	.023	.011	.112	.064	4.9	5.8
Canadian						
337-38	.025	.015	.205	.112	8.2	7.5
1303-04	.013	.013	.088	.082	6.8	6.3
1307-08	.008	.007	.165	.147	20.6	21.0
1309-10	.014	.009	.035	.033	5.9	3.3
1311-12	.017	.017	.081	.056	4.8	3.3
1315-16	.015	.013	.121	.070	8.1	5.4
1319-20	.015	.010	.090	.055	6.0	5.5
1321-22	.015	.012	.104	.077	6.9	6.4
1323-24	.014	.009	.092	.079	6.6	8.8
1325-26	.041	.039	.151	.094	3.7	2.4
1327-28	.025	.016	.110	.095	4.4	5.9
1329-30	.017	.009	.112	.060	6.6	6.7
1331-32	.011	.014	.053	.060	4.8	4.3
1333-34	.033	.013	.132	.082	4.0	6.3
1335-36	.014	.004	.060	.065	4.3	16.0
1337-38	.013	.012	.114	.100	7.8	8.3
1339-40	.013	.010	.115	.079	8.9	7.9
1341-42	.017	.009	.119	.077	7.0	8.6
1343-44	.010	.011	.057	.033	5.7	3.0
1345-46	.011	.006	.056	.056	5.1	9.3
1347-48	.018	.011	.147	.049	8.2	4.5
1477-78	.030	.012	.191	.065	6.4	5.4
1513-14	.010	.005	.125	.033	12.5	6.6
1545-46	.049	.034	.205	.154	4.2	4.5
Carter						
203-04	.017	.014	.120	.089	7.1	6.4
1405-06	.035	.030	.243	.081	6.9	2.7
1421-22	.009	.006	.095	.082	10.5	13.7
1633-34	.020	.018	.145	.077	7.3	4.3
Choctaw						
393-94	.019	.014	.096	.088	5.1	6.3

Table 1—(Continued)

County and Soil Number	Sulfur in Percent		Nitrogen in Percent		Nitrogen-Sulfur Ratio	
	Virgin	Cropped	Virgin	Cropped	Virgin	Cropped
Comanche						
1493-94	.020	.015	.094	.066	4.7	4.4
4172-74	.011	.009	.090	.084	8.2	9.3
4176-78	.016	.016	.120	.103	7.5	6.4
4180-82	.070	.049	.188	.112	2.7	2.3
Cotton						
379-90	.020	.015	.134	.053	6.7	3.5
4204-06	.015	.010	.165	.067	11.0	6.7
4208-10	.014	.007	.151	.092	10.8	13.2
Craig						
1553-54	.025	.022	.160	.067	6.4	3.1
Custer						
4269-71	.018	.012	.160	.070	8.9	5.8
Dewey						
1453-54	.027	.019	.184	.128	5.8	6.7
Ellis						
259-60	.011	.016	.082	.075	7.5	4.7
1613-14	.020	.019	.103	.100	5.2	5.3
4128-30	.012	.009	.084	.058	7.0	6.5
Garfield						
413-14	.024	.014	.187	.104	7.8	7.4
1469-70	.016	.012	.128	.052	8.0	4.3
1497-98	.017	.004	.162	.096	9.5	24.0
Garvin						
299-300	.013	.010	.230	.076	16.4	7.6
Grady						
185-86	.019	.017	.132	.097	6.9	5.7
1397-98	.021	.011	.067	064	3.2	5.8
4104-06	.013	.009	.128	.070	9.8	7.8
4108-10	.012	.011	.075	.061	10.7	5.5
4112-14	.017	.010	.128	.084	7.5	8.4
4116-18	.017	.009	.115	.061	6.8	6.8
4120-22	.016	.015	.086	.081	5.4	5.4
Grant						
267-68	.038	.016	.112	.104	2.9	6.5
297-98	.022	.013	.071	.045	3.2	3.5
1265-66	.032	.015	.187	.089	5.8	5.3
4236-38	.020	.011	.171	.123	8.5	11.0
4240-42	.018	.008	.070	.078	3.9	9.8
Greer						
211-12	.014	.013	.100	.092	7.1	6.6
1465-66	.014	.006	.119	.120	8.5	20.0
1597-98	.024	.015	.134	.065	5.6	4.3
4220-22	.024	.015	.229	.092	9.5	6.2
Harmon						
177-78	.016	.020	.113	.127	7.1	6.4
4216-18	.062	.036	.193	.095	3.1	2.6
Harper						
369-70	.025	.026	.143	.148	5.7	5.7
1281-82	.025	.018	.113	.089	4.5	4.9

Table 1—(Continued)

County and Soil Number	Sulfur in Percent Virgin	Sulfur in Percent Cropped	Nitrogen in Percent Virgin	Nitrogen in Percent Cropped	Nitrogen-Sulfur Ratio Virgin	Nitrogen-Sulfur Ratio Cropped
Hughes						
341-42	.015	.008	.119	.076	7.9	9.5
1393-94	.021	.019	.126	.100	6.0	5.3
1561-62	.017	.016	.020	.059	1.2	3.7
Jackson						
407-08	.030	.019	.216	.136	7.2	7.2
1253-54	.012	.010	.058	.034	4.8	3.4
1481-82	.006	.006	.071	.059	11.8	9.8
1593-94	.023	.040	.072	.069	3.1	1.7
4212-14	.026	.017	.196	.137	7.5	8.1
Jefferson						
167-68	.013	.009	.115	.091	8.9	10.1
1601-02	.008	.012	.042	.033	5.3	2.9
Johnston						
173-74	.006	.004	.038	.033	6.3	8.2
Kiowa						
421-22	.049	.019	.136	.062	2.9	3.3
1293-94	.020	.019	.111	.081	5.6	4.3
4248-50	.013	.008	.101	.098	7.8	12.3
4252-54	.009	.009	.098	.104	10.9	11.6
Le Flore						
389-90	.029	.021	.195	.159	6.7	7.6
1413-14	.013	.009	.127	.052	9.8	5.8
Lincoln						
1389-90	.022	.040	.101	.059	4.6	1.5
Logan						
169-70	.012	.014	.124	.119	10.3	8.5
1485-86	.029	.007	.107	.067	3.7	9.6
Mayes						
4244-46	.012	.010	.137	.106	11.4	10.6
McClain						
1461-62	.033	.014	.113	.078	3.4	5.6
4096-98	.007	.002	.126	.067	18.0	33.5
4100-02	.009	.002	.084	.039	9.3	19.5
McCurtain						
161-62	.013	.008	.147	.096	11.3	12.0
1537-38	.007	.006	.063	.044	9.0	7.3
1573-74	.023	.016	.182	.077	7.9	4.8
McIntosh						
4256-58	.013	.002	.160	.126	12.3	63.0
Murray						
197-98	.021	.008	.152	.042	7.2	5.3
Muskogee						
435-36	.018	.015	.172	.073	9.5	4.9
1529-30	.020	.007	.234	.092	11.7	13.1
1541-42	.033	.021	.335	.068	10.1	3.2
4168-70	.007	.007	.086	.075	12.3	10.7
Noble						
600-01	.017	.010	.113	.049	6.6	4.9

Table 1—(Continued)

County and Soil Number	Sulfur in Percent Virgin	Sulfur in Percent Cropped	Nitrogen in Percent Virgin	Nitrogen in Percent Cropped	Nitrogen-Sulfur Ratio Virgin	Nitrogen-Sulfur Ratio Cropped
Nowata						
205-06	.014	.008	.119	.079	8.5	9.9
1401-02	.027	.022	.126	.085	4.7	3.9
1625-26	.104	.075	.241	.144	2.3	1.9
Okfuskee						
159-60	.022	.018	.175	.117	7.9	6.5
163-64	.017	.009	.193	.104	11.4	11.6
Oklahoma						
283-84	.024	.014	.168	.147	7.0	10.5
1505-06	.005	.004	.061	.041	12.2	10.3
Okmulgee						
351-52	.015	.013	.127	.098	8.5	7.5
Osage						
1285-86	.020	.019	.127	.087	6.4	4.6
Pawnee						
263-64	.034	.017	.210	.103	6.2	6.1
1473-74	.025	.019	.197	.115	7.9	6.1
Payne						
247-48	.021	.022	.158	.131	7.5	6.0
1409-10	.016	.012	.105	.075	6.6	6.3
1501-02	.022	.015	.098	.099	4.5	6.6
1525-26	.013	.012	.134	.158	10.3	13.1
1557-58	.021	.017	.126	.080	6.0	4.7
1577-78	.024	.013	.164	.056	6.8	4.3
1617-18	.008	.012	.065	.039	8.1	3.2
Pittsburg						
1521-22	.046	.030	.276	.124	6.0	4.1
1605-06	.023	.014	.173	.078	7.5	5.6
4132-34	.014	.012	.151	.101	10.8	8.4
4136-38	.019	.012	.218	.095	11.5	7.9
4140-42	.016	.010	.140	.087	8.8	8.7
4144-46	.014	.011	.156	.078	11.1	7.1
4148-50	.016	.014	.151	.106	9.4	7.6
4152-54	.029	.007	.045	.067	1.6	9.6
4156-58	.025	.020	.131	.061	5.3	3.0
4260-62	.020	.006	.165	.067	8.3	10.1
4273-75	.016	.012	.076	.050	4.8	4.2
Pontotoc						
1637-38	.015	.009	.138	.088	9.2	9.8
Pottawatomie						
181-82	.019	.009	.140	064	7.8	7.1
Roger Mills						
1055-56	.023	.014	.132	.066	5.7	4.7
Rogers						
155-56	.021	.021	.190	.160	9.0	7.6
359-60	.047	.036	.384	.236	8.2	6.6
Seminole						
1621-22	.012	.004	.093	.035	7.8	8.8
Sequoyah						
1381-82	.018	.018	.120	.090	6.6	5.0
1417-18	.023	.023	.154	.086	6.7	3.7

Table 1—(Continued)

County and Soil Number	Sulfur in Percent Virgin	Sulfur in Percent Cropped	Nitrogen in Percent Virgin	Nitrogen in Percent Cropped	Nitrogen-Sulfur Ratio Virgin	Nitrogen-Sulfur Ratio Cropped
Stephens						
251-52	.019	.012	.123	.027	6.5	2.2
1489-90	.005	.001	.089	.025	17.8	25.0
1565-66	.017	.011	.172	.085	10.1	7.7
4184-86	.027	.016	.154	.098	5.7	6.1
4188-90	.015	.004	.134	.036	8.9	9.0
Texas						
309-10	.019	.014	.100	.106	5.3	7.6
Tillman						
175-76	.020	.011	.112	.070	5.6	6.4
179-80	.019	.014	.134	.091	7.1	6.5
1533-34	.008	.006	.065	.050	8.1	8.3
1629-30	.005	.005	.058	.056	11.6	11.2
4224-26	.015	.012	.092	.070	6.2	5.8
4228-30	.018	.016	.165	.115	9.2	7.2
4232-34	.025	.013	.224	.126	9.0	9.7
Wagoner						
375-76	.015	.006	.126	.054	8.4	9.0
Washington						
195-96	.022	.022	.178	.102	8.1	4.6
Washita						
1457-58	.022	.015	.152	.120	6.9	8.0
1569-70	.020	.016	.112	.079	5.6	4.4
Woods						
377-78	.025	.022	.191	.131	7.6	5.9
4160-62	.017	.016	.140	.131	8.2	8.2
4164-66	.005	.005	.095	.072	19.0	14.4
Woodward						
201-02	.006	.005	.045	.049	7.5	9.8
271-72	.019	.017	.162	.091	8.5	5.4
1517-18	.008	.007	.053	.055	6.6	7.9
Average	.0197	.0139	.1314	.0827	7.5	7.6

Table 2.—Total Sulfur, Nitrogen and Phosphorus Content, and Nitrogen-Sulfur and Phosphorus-Sulfur Ratios of Eighteen Oklahoma Soil Profiles.

Soil Type, County, and Sample Number	Depth in Inches	pH Value	Total Phosphorus	Total Sulfur	Total Nitrogen	Nitrogen Sulfur Ratio	Phosphorus Sulfur Ratio
			%	%	%		
Bates fine sandy loam; Craig County							
2441	0-3	5.3	.022	.021	.203	9.66	1.05
2442	3-13	5.1	.020	.009	.091	10.11	2.22
2443	13-19	5.1	.021	.007	.072	10.28	3.00
2444	19-29	5.3	.023	.006	.065	10.83	3.83
2445	29-34	6.5	.042	.002	.037	18.50	21.00

Table 2—(Continued)

Soil Type, County, and Sample Number	Depth in Inches	pH Value	Total Phos-phorus	Total Sulfur	Total Nitrogen	Nitrogen Sulfur Ratio	Phosphorus Sulfur Ratio
			%	%	%		
Bates very fine sandy loam; Tulsa County							
3970	0-11	5.6	.012	.016	.124	7.75	.75
3971	11-17	5.7	.010	.012	.095	7.91	.83
3972	17-23	5.9	.010	.008	.077	9.62	1.25
3973	23-31	6.3	.008	.010	.062	6.17	.80
3974	31-40	7.1	.006	.008	.037	4.62	.75
Bates very fine sandy loam; Okmulgee County							
4493	0-6	5.7	.014	.010	.084	8.40	1.40
4494	6-12	5.8	.014	.005	.084	16.80	2.80
4495	12-18	5.8	.013	.005	.081	16.20	2.60
4496	18-24	5.8	.016	.006	.077	12.83	2.67
4497	24-30	7.0	.018	.005	.067	13.40	3.60
4498	30-36	7.7	.022	.004	.053	13.25	5.50
Durant fine sandy loam; Murray County							
3662	0-11	7.0	.066	.010	.110	11.00	6.60
3663	11-22	5.5	.030	.011	.100	9.09	2.72
3664	22-27	5.5	.031	.004	.065	16.25	7.75
3665	27-38	6.1	.066	.005	.058	11.60	13.20
3666	38-50	6.1	.032	.002	.038	19.00	16.00
Kirkland very fine sandy loam; Cleveland County							
4457	0-6	6.9	.011	.010	.101	10.10	1.10
4458	6-12	7.8	.010	.006	.067	11.16	1.67
4459	12-18	8.1	.009	.009	.064	7.11	1.00
4460	18-24	8.4	.009	.008	.051	6.37	1.13
4461	24-30	8.5	.011	.011	.039	3.54	1.00
4462	30-36	8.5	.021	.019	.039	2.05	1.11
Kirvin very fine sandy loam; Choctaw County							
6123	0-4	7.3	.009	.006	.053	8.83	1.50
6124	4-8	7.0	.008	.002	.022	11.00	4.00
6125	8-15	5.3	.006	.001	.031	31.00	6.00
6126	15-24	4.6	.016	.006	.031	5.16	2.67
6127	24-36	4.6	.007	.001	.034	34.00	7.00
Pond Creek very fine sandy loam; Garfield County							
3814	0-3	6.5	.056	.021	.200	9.52	2.67
3815	3-6	6.8	.042	.012	.120	10.00	3.50
3816	6-14	7.1	.043	.008	.092	11.50	5.38
3817	14-25	6.9	.056	.009	.080	8 88	6.22
3818	25-42	7.3	.056	.009	.050	5.56	6.22
Pratt loamy fine sand; Woods County							
6601	0-10	6.2	.011	.006	.059	9.83	1.83
6602	10-19	6.8	.011	.005	.031	6.20	2.20
6603	19-34	6.7	.009	.005	.031	6.20	1.80
6604	34-50	6.8	.010	.005	.017	3.40	2.00
Renfrow very fine sandy loam; Garfield County							
3822	0-6	7.4	.062	.022	.160	7.27	2.82
3823	6-10	7.0	.059	.016	.144	9.00	3.69
3824	10-22	7.1	.048	.011	.090	8.18	4.36
3825	22-30	7.9	.046	.007	.068	9.71	6.57
3826	30+	8.1	.049	.004	.063	15.75	12.25

Table 2—(Continued)

Soil Type, County, and Sample Number	Depth in Inches	pH Value	Total Phos- phorus	Total Sulfur	Total Nitrogen	Nitrogen Sulfur Ratio	Phosphorus Sulfur Ratio
			%	%	%		
Renfrow fine sandy loam;* Payne County							
6529	0-6	5.6	.028	.017	.119	7.00	1.65
6530	6-12	5.9	.025	.018	.101	5.61	1.39
6531	12-18	6.7	.020	.012	.076	6.33	1.67
6532	18-24	7.2	.017	.012	.057	4.75	1.42
6533	24-36	7.8	.015	.017	.041	2.41	.88
6534	36-48	8.0	.014	.011	.032	2.91	1.27
Renfrow fine sandy loam; Payne County							
6559	0-6	5.1	.023	.014	.087	6.21	1.64
6560	6-12	5.7	.023	.018	.091	5.06	1.28
6561	12-18	6.4	.018	.011	.077	7.00	1.64
6562	18-24	6.7	.017	.009	.057	6.33	1.89
6563	24-36	7.0	.013	.004	.042	10.50	3.25
6564	36-48	7.1	.011	.006	.030	5.00	1.83
Richfield silt loam; Texas County							
2325	0-6	7.7	.038	.012	.095	7.92	3.17
2326	12-18	8.7	.038	.008	.068	8.50	4.75
Richfield silt loam; Beaver County							
2341	0-6	7.4	.049	.027	.145	5.37	1.81
2342	12-18	7.6	.039	.017	.087	5.11	2.29
San Saba clay; Choctaw County							
6082	0-6	7.5	.027	.049	.189	3.86	.55
6083	6-12	7.6	.023	.044	.173	3.93	.52
6084	12-20	7.6	.019	.032	.134	4.19	.59
6085	20-40	7.6	.011	.037	.075	2.03	.30
St. Paul silt loam; Washita County							
6150	0-5	6.5	.028	.012	.114	9.50	2.33
6151	5-12	6.9	.023	.013	.137	10.54	1.74
6152	13-24	7.5	.021	.004	.061	15.25	5.25
6153	24-36	8.2	.013	.007	.045	6.43	1.86
6154	36-50	8.4	.013	.007	.039	5.57	1.86
Summit clay; Craig County							
2415	0-13	8.1	.043	.034	.205	6.03	1.26
2416	13-20	7.9	.043	.033	.216	6.55	1.30
2417	20-33	8.3	.027	.017	.098	5.76	1.59
2418	33-48	8.5	.024	.013	.076	5.85	1.85
2419	48-70	8.5	.020	.006	.094	15.67	3.33
2420	70-80	8.7	.023	.004	.073	18.25	5.75
Tillman clay loam; Kiowa County							
1741	0-4	7.8	.025	.020	.122	6.10	1.25
1742	4-12	7.5	.022	.015	.126	8.40	1.47
1743	12-24	7.2	.015	.013	.072	5.54	1.15
1744	24-42	8.6	.013	.011	.044	4.00	1.18
1745	42-60	8.9	.018	.036**	.022	.61	.50
1746	60-84	9.2	.026	.059**	.023	.39	.44
St. Paul very fine sandy loam; Woodward County							
3175	0-8	8.0	.033	.011	.084	7.64	3.00
3176	8-15	7.8	.030	.010	.058	5.80	3.00
3177	15-36	7.8	.030	.014	.039	2.79	2.14
3178	36-48	8.3	.039	.008	.024	3.00	4.88
3179	48-54	8.5	.042	.008	.009	1.13	5.25

* Received farm manure as compared with the following profile (Soil No. 6559-64) which was obtained from an unfertilized plot.

** Inorganic sulfur present.

Table 3.—Content of sulfur as water soluble sulfates in soil layers from eight locations in eight Oklahoma counties.
(parts per million)

No.	Soil type	Location	depth in feet 0-1	1-2	2-3	3-4	4-5	5-6	6-7
1	Grant very fine sandy loam	3 mi. S., Jet	.5	.3	1.4	.5	.7	1.0	.3
2	Kirkland silt loam	2 mi. S., Deer Creek	.8	1.5	5.9	3.2	5.2	6.3	7.1
3	Kirkland silt loam	1 mi. W., Stillwater	13.7	31.8	40.0	373.2	187.6	125.6	118.0
4	Newkirk silt loam	3 mi. S., Blackwell	1.5	3.1	3.3	1.1	1.6	1.9	1.0
5	Parsons silt loam	3 mi. N. W., Beggs	.1	1.2	2.3	2.3	1.5	4.4	1.2
6	Parsons silt loam	1 mi. E., Welch	2.0	1.7	7.0	8.9	*	*	*
7	Parsons silt loam	1 mi. S. E., Pryor	2.5	16.6	39.6	332.8	125.8	5.6	36.6
8	Pratt loamy sand	11 mi. S. W., Lahoma	1.4	.3	.3	.3	.1	.3	.5
9	Pratt sandy loam	5 mi. S. E., Hennessey	.8	.8	.3	.3	.4	.3	.3
10	Reinach clay loam	3 mi. W., Sand Springs	1.1	.5	.8	.4	1.0	.5	.8
11	Vanoss silt loam	2 mi. N. W., Crescent	.3	.8	3.7	5.1	5.2	7.0	*

* No samples taken.

Table 4.—Sulfur Content of Oklahoma Rainfall.
(pounds in annual rainfall on one acre)

Year	Stillwater*	Guthrie	Lone Grove	Goodwell	Heavener
1927	6.85				
1928	8.49				
1929	11.72				
1930	7.32				
1931	8.41	7.3			
1932	7.10	--			
1933	12.68	5.6		5.9	
1934	6.17	7.5	7.6	5.8	17.9
1935	7.85	--	--		
1936	7.75	--	11.7		
1937	12.56	12.6			
1938	11.34	5.9			
1939	6.47	8.9			
1940	**				
1941	6.20				
1942	10.11				
Average	8.73				

* Rainfall contained an average of 1.52 ppm of sulfur the first quarter, 1.35 ppm the second quarter, 1.03 ppm the third quarter and 1.74 ppm the fourth quarter.
** No data obtained in 1940.

Table 5.—Quantity of sulfur absorbed from the atmosphere as sulfur dioxide on a lead peroxide coated fabric at Stillwater, Okla., and at St. Paul and Bemidji, Minn.; July 1, 1941 to June 30, 1942.*
(pounds of sulfur per acre)

	Stillwater, Okla.	St. Paul, Minn.	Bemidji, Minn.
1941			
July	.29	4.58	.20
August	.41	8.99	.30
September	.38	6.90	.12
October	.38	10.94	.24
November	.50	17.54	.22
December	.81	19.59	.37
1942			
January	.71	23.93	.26
February	.75	12.08	.40
March	.44	18.20	.43
April	.32	8.25	.18
May	.29	6.65	.17
June	.10	7.52	.11
Total, 12 mos.	5.38	145.17	3.00

* Analyses made by Dr. F. J. Alway, St. Paul, Minnesota.

Appendix

Method for Determining the Total Sulfur in Soil

The following method for the determination of total sulfur in soil was developed in the Soils Laboratory of the Oklahoma State University for routine analysis. Results obtained by this method were in good agreement with those obtained by sodium peroxide fusion of soil in a Parr bomb.

Procedure

Weigh five grams of 100-mesh oven-dry soil into a 250 ml Pyrex beaker and add 40 ml of a freshly prepared solution containing 4% of NaOH and 3% of $KMn0_4$. Cover beaker with a watch glass, place on a hot plate, and boil gently for one hour. If the liquid turns green due to the complete reduction of the $KMn0_4$, add 5 to 10 ml of 3% $KMn0_4$ and continue heating.

After digestion is complete, cool beaker and add slowly 50 ml of 1 to 1 hydrochloric acid with a pipette under a well-ventilated hood. Place beaker on a hot plate and heat until the residue is light yellow in color, or until all $Mn0_2$ is in solution. Dilute to 100 ml, heat to boiling, and precipitate the iron and aluminum by adding ammonia (1 part of conc. NH_4OH to 2 parts of distilled water) until the solution is basic to a strip of litmus paper placed on the inside wall of beaker. Allow the precipitated hydroxides to settle and filter while hot through a 15 cm Whatman No. 1 filter paper into a 400 ml beaker containing 5 ml of 1 to 1 HCl.

Wash beaker twice, and precipitate four times with hot water. Punch a hole through bottom of filter paper in funnel with a pointed glass rod and wash precipitate into original beaker. Pour 10 ml of 1 to 1 HCl over filter to dissolve adhering hydroxides and wash once with hot water. Dilute to approximately 100 ml with distilled water, heat to boiling, and precipitate the iron and aluminum as before. Filter into beaker containing the first filtrate, which must be acid, and wash beaker and precipitate four or five times with hot water. Neutralize filtrate with ammonium hydroxide (1 to 2) using 5 drops of 1% methyl red indicator. Reduce volume to 300 ml, add 3 ml of 1 to 1 HCl (1 ml per 100 ml of filtrate if less than 300 ml), heat to boiling, and add slowly with constant stirring 5 ml of 10% barium chloride solution. Cover beaker with a watch glass, and keep solution near the boiling point for one hour.

Allow solution containing the precipitate to stand at room temperature over night, or longer, and then filter through a 11 cm Whatman No. 42 filter paper, or its equivalent. Wash precipitate and filter paper

12 to 15 times with hot water containing 10 ml of 1 to 1 HCl per liter and finally 8 to 10 times with hot water, or until all chlorides are removed. Place filter paper containing the precipitate in a weighed platinum or porcelain crucible and ignite to constant weight, preferably in an electric furnace at 800° C. Multiply weight of barium sulfate in milligrams by .002747 to calculate percent of sulfur in a 5 gram sample of soil.

Notes

A smaller soil sample should be used when soils high in organic matter are analyzed. A larger soil sample should be used when the total sulfur content of a soil is very low. Excessive frothing during the digestion of high organic matter soils can be reduced by heating at a lower temperature. Acid must be placed in the beaker used to collect the filtrate from the sesqueoxide precipitation to prevent the formation of manganous hydroxide, which cannot be dissolved readily in dilute acid or removed easily by filtration.

The acidity of the solution in which the barium sulfate is precipitated should be adjusted to pH 1.0. Low results due to increased solubility of the precipitate will be obtained if the pH is much lower than 1.0. Positive errors from absorption and/or occlusion of salts by the barium sulfate will occur if the pH is much above this value. When the quantity of barium sulfate precipitate is very small, increased accuracy may be obtained by allowing the solution containing the precipitate to stand for 36 to 48 hours before filtering.

If 3 mgs. of potassium sulfate are added to the blank and to each of the soil filtrates before the barium chloride solution is added, negative errors due to slow crystallization of barium sulfate when the sulfate content is very low, or to increased solubility of the barium sulfate when the solution is too acid, can be reduced.

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