EFFECT OF FERTILIZERS ON SOIL ACIDITY AND ALKALINITY

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A high percentage of the soils in central and eastern Oklahoma are acid and low in available phosphorus. These soils need legume rotations and proper fertilization to maintain or increase crop yields. Use of legumes and fertilizers affects the reaction (acidity or alkalinity) of the soil, and soil fertility improvement programs must take account of this fact. This publication was prepared to summarize available information on the effect of fertilization on soil reaction.

AMMONIA AND PROTEIN NITROGENS INCREASE ACIDITY

Ammonium salts, or fertilizer containing protein nitrogen such as urea and cottonseed meal, have an acidifying effect on soil. Their continued use, either alone or in fertilizer mixtures, will slowly neutralize any excess of lime which may be present in the soil, or increase acidity if the soil is already acid. On the other hand, nitrogen applied in the form of sodium nitrate, calcium nitrate or calcium cyanamide tends to prevent the formation of soil acidity. Consequently, nitrogen in the form of nitrates or combined with an acid-neutralizing base (e. g., calcium cyanamide), may be better on an acid soil than will a nitrogen fertilizer which tends to increase acidity.

The nitrogen in ammonium sulfate will produce about twice as much acidity in a soil as the nitrogen in legume residues or in such fertilizer materials as urea or cottonseed meal.[1] Therefore the cost of adding lime to neutralize the acidity produced by ammonium sulfate must be considered in calculating the beneficial effects of this fertilizer. Each pound of ammonium

[1] Ammonium sulfate reacts with the calcium or other bases combined with clay minerals to form calcium sulfate and ammonium clay. A high percentage of the ammonia on the ammonium clay is eventually changed to nitric acid, leaving an acid clay mineral. The nitric acid reacts with more calcium, leaving two particles of acid clay. Similar reactions occur when ammonium nitrate, or ammonium phosphate, is applied to a soil.

sulfate would require about 8 or 9 pounds of agricultural limestone to neutralize the acidity produced.[2]

A strongly acid condition has developed in many southern soils where ammonium sulfate and other acid-forming nitrogen materials have been applied in fertilizer mixtures. Finely ground limestone or dolomite is sometimes added in place of sand in a fertilizer formula containing ammonia nitrogen to produce a "neutral" fertilizer.

The effect of ammonium sulfate and sodium nitrate on the reaction of soil was determined in a fertilizer experiment on a native grass meadow on the Oklahoma station farm after various applications had been made over a 15-year period. Ammonium sulfate increased the acidity of the surface soil. Sodium nitrate did not affect the reaction of the surface soil but reduced the acidity of the subsurface soil. The results of this study are given in Tables I and II. Treatments began in 1929. Soil samples were collected for analyses in 1943. Ammonium sulfate was applied at the rate of 200 pounds per acre and the sodium nitrate at the rate of 274 pounds per acre, annually. The average pH of the plot receiving the ammonium sulfate decreased .7 in the surface 0 to 3 inches and .2 in the layer 3 to 6 inches deep, as compared with adjacent soil which received no fertilizer treatment. No apparent change occurred in the soil layer 6 to 12 inches deep. The sodium nitrate treatment has prevented any increase in surface acidity. The subsurface soils averaged .3 to .4 pH higher than the same horizon in the unfertilized plots.

The effect of various fertilizer treatments on soil reaction in tests conducted at four different agricultural experiment stations is shown in Table III. Soil fertilized with minerals and ammonium sulfate on the Jordan plots at State College, Pennsylvania, is nearly fifty times as acid as the untreated land. In an experiment at Woburn, England, the acidity is approximately ten times greater on the ammonium sulfate plot than on the unfertilized soil. In South Carolina and New Jersey experiments, the acidity of plots treated with ammonium

[2] Each pound of nitrogen added to the soil by applying ammonium sulfate containing 20.8% nitrogen would require 7.43 pounds of calcium carbonate to neutralize the acidity produced if all of the ammonia nitrogen were oxidized to nitric acid before being absorbed by plant roots. This quantity of calcium carbonate would be equivalent to 8.25 pounds of agricultural limestone having a neutralizing value of 90%. Four hundred pounds of a 5-10-5 fertilizer contains 20 pounds of nitrogen, which if present as ammonium sulfate would require 160 to 180 pounds of limestone to neutralize the acidity produced. The nitrogen in some mixed fertilizer is present as ammonium phosphate. It has about the same acidifying effect on a soil as ammonium sulfate.

*TABLE I. Effect of ammonium sulfate on soil reaction (pH), 1929 to 1943.**

NO TREATMENT				AMMONIUM SULFATE 200 lbs. per acre annually			
Plot No.	pH at depth: 0-3″	3-6″	6-12″	Plot No.	pH at depth: 0-3″	3-6″	6-12″
10	6.1	6.1	5.8	9	5.2	5.7	5.8
13	6.1	5.9	5.9	12	5.3	5.7	5.8
22	6.5	6.2	6.1	21	5.8	6.0	6.2
25	6.2	6.0	5.9	24	5.7	6.0	6.1
Av.	6.2	6.0	5.9	Av.	5.5	5.8	6.0

* Prairie hay study. Series 4400; Oklahoma Agricultural Experiment Station Farm, Stillwater.

*TABLE II. Effect of sodium nitrate on soil reaction (pH), 1929 to 1943.**

Plot No.	No treatment			Plot No.	Annual application of sodium nitrate 274 lbs. per acre		
	0-3	3-6	6-12		0-3	3-6	6-12
7	6.1	5.8	5.7	8	6.0	6.1	6.2
10	6.1	6.1	5.8	11	5.9	6.0	6.1
19	6.4	6.2	6.2	20	6.4	6.6	6.7
22	6.2	6.0	5.9	23	6.3	6.5	6.6
Av.	6.2	6.0	5.9	Av.	6.1	6.3	6.4

* Prairie hay study. Series 4400; Oklahoma Agricultural Experiment Station Farm, Stillwater.

sulfate is four to five times as great as the acidity of unfertilized soils. Ammonium sulfate and ammonium phosphate increased acidity more than urea at the PeeDee Experiment Station at Florence, South Carolina. Calcium cyanamide decreased the acidity of this soil as compared to plots which received superphosphate and potash without nitrogen.

SUPERPHOSPHATE AND POTASH FERTILIZERS MAKE LITTLE CHANGE IN ACIDITY

Superphosphate and potash fertilizers have very little influence on soil reaction. The data presented in Table III show that superphosphate on the Jordon plots at State College, Pennsylvania, decreased the pH about .2 over a fifty-year period, whereas superphosphate and muriate of potash increased the pH about .3. Superphosphate and muriate of potash decreased the pH in the New Jersey experiment and in the experiment at Woburn, England.

TABLE III. Effect of continued use of various fertilizers without lime on pH value of surface soils.

No.	Fertilizer applied	Pa. Agri. Exp. Sta., State College, Pa. Jordan Plots, 1881-1921		N. J. Agri. Exp. Sta., New Brunswick, N. J. Cylinder Studies 1898-1938		Woburn Exp. Sta., Woburn, England Stackyard Field 1877-1927			PeeDee Exp. Sta., Florence, S. C. Cotton Experiment, 1931-1939	
		Rate per A. (lbs.)	pH value	Rate per A. (lbs.)	pH value	Rate per A. (lbs.)	pH value		Rate per A. (lbs.)	pH value
							Barley Plot	Wheat Plot		
1	None		5.98		4.90		5.3	5.1		
2	Superphosphate	$48P_2O_5$	6.18							
3	Superphosphate	$48P_2O_5$	5.68	640	5.10	300**	5.9	5.8	$100P_2O_5$	5.88
	Muriate of potash	$100K_2O$		320		50**			$50K_2O$	
4	Minerals and sodium nitrate	72N	5.64	160	5.10	18.4N	5.8	5.7	200	5.93
5	Minerals and sodium nitrate			320	5.20	36.8N	6.2	6.3		
6	Minerals and ammonium sulfate	72N	4.55	*	4.10	18.4N†	4.4	4.0	††	5.48
7	Minerals and dried blood	72N	5.15	*	4.40					
8	Farmyard manure			16T.	4.95	74N	5.8	6.3		
9	Ammonium phosphate								††	5.32
10	Urea								††	5.63
11	Calcium cyanamide								††	6.46

* Equivalent to 320 lbs. $NaNO_3$.

** Since 1906. Potassium sulfate applied instead of muriate of potash. 3.50 cwt. of superphosphate, 1.79 cwt. sulfate potash, .90 cwt. of sodium sulfate and .9 cwt. of magnesium sulfate applied annually from 1877 to 1906.

† Equal weight of ammonium sulfate and chloride applied until 1907 and the rate was double that given in the table.

†† Nitrogen equivalent to 300 lbs. of sodium nitrate.

FERTILIZER MATERIALS WHICH NEUTRALIZE ACIDITY

Basic slag and to some extent finely ground rock phosphate often contain a small percentage of calcium carbonate or other forms of calcium which can combine with soil acids. These fertilizers tend to correct some of the acidity in acid soils when high rates of application are used.

Wood ashes contain a considerable quantity of calcium carbonate. The average is about 55 percent. Cotton bur ashes contain a high percentage of potassium carbonate; analyses made at the Oklahoma Station show that the average sample contains about 65 percent. These ashes applied to an acid soil will neutralize acidity. The change in reaction will depend upon the quantity applied and the texture of the soil. Normally the change will be greater in sandy soils than in fine texture soils. A large application of cotton bur ashes may be harmful to plant growth if applied on a neutral or slightly acid soil because of the high alkalinity produced by the potassium carbonate.

FARMYARD MANURE DECREASES ACIDITY

Farmyard manure added to a soil at regular intervals over a long period of time will reduce or greatly retard the development of soil acidity. Manure usually contains more of the inorganic base-forming elements such as calcium, potassium, and magnesium than acid-forming elements such as nitrogen, phosphorus, and sulfur. Experiments at several state experiment stations show that plots receiving barnyard manure are less acid than adjacent unfertilized soils. At the Oklahoma Station over a forty-year period a manure application equivalent to 3.6 tons per acre each year has retarded the formation of soil acidity and increased the supply of exchangeable calcium in the surface soil, as shown in Table IV. Soil samples collected in 1926, 28 years after the experiment was started, were tested for acidity. Virgin soil adjacent to the experimental plot had a pH of 6.1. Manured soil had a pH of 5.7, and unmanured land a pH of 5.3. In 1938 the manured soil had a pH of 5.6, the unmanured land a pH of 5.1. No virgin soil was available for comparison in 1938. The soil on which this experiment is located has a neutral subsoil at a depth of 18 to 24 inches.

*TABLE IV. Effect of farmyard manure on soil reaction and fertility of land planted continuously to wheat for 40 years.**

Treatment	pH value	Exchangeable calcium (%)	Easily soluble phosphorus**	Total nitrogen (%)	Total organic matter (%)
Manured plot	5.6	.109	40	.119	2.32
No fertilizer	5.1	.064	12	.087	1.69

* Oklahoma Agricultural Experiment Station Farm, Stillwater. Soil samples collected in 1938.

** Fifth normal sulfuric acid extraction in parts per million. Soil-acid ratio 1 to 10.

Garden soils heavily fertilized with farmyard manure or wood ashes may develop a slightly alkaline reaction. Stunted plants are frequently observed in some gardens where soil alkalinity is high and the active organic matter content has not been maintained by frequent application of farmyard manure or other types of organic matter. As the active organic matter declines from continued cultivation, the availability of phosphorus and other plant nutrients such as manganese may be too low for best growth of vegetables. About the only recommendation that can be made under such conditions is to increase the supply of active organic matter in the soil. As organic matter decays, carbon dioxide is released which will reduce the alkalinity by changing calcium carbonate to calcium bicarbonate and create a more favorable condition for the absorption and utilization of essential nutrients by plant roots.

Soil alkalinity may also be reduced by the addition of sulfur or other acid-forming materials. The cost of treatment is rather high for a large area. However, it is frequently used to correct the harmful effect of "black alkali" in irrigated soil.

LEGUME RESIDUES INCREASE ACIDITY

The average legume contains from 2 to 3 percent of total nitrogen in the dry residue when the crop is mature. About two-thirds of the nitrogen in a legume comes from the air. If one ton of legume residue containing 2.5 percent of nitrogen were returned to a soil and all of the nitrogen were oxidized to nitric acid during the process of decay, it would take about 275 pounds of the average agricultural limestone (90 percent calcium carbonate) to correct the acidity produced by that portion of the nitrogen which came from the air. The quantity

of calcium required to neutralize acidity formed from the oxidation of organic nitrogen is usually slightly lower than the calculated amount because some nitrogen compounds are used by plants before they are converted to nitric acid.

Korean lespedeza sometimes makes a good growth on moderately acid soils for a few years and then the yields decline. Similar conditions can be observed with other acid-tolerant legumes. Increased soil acidity produced by decay often is the cause of this condition.

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