# Oxidation of Sulfur in Soils

## nitrogen losses during oxidation may cause temporary setback to plants following applications of sulfur

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**Nitrogen disappears** especially rapidly from soils which are naturally high in mineral nitrogen or which receive heavy applications of fertilizer nitrogen.

Part of the nitrogen losses can be accounted for by leaching. The remainder is presumed to disappear through volatilization and transformation to nitrogen gas.

In the reduction of nitrates to nitrogen gas by certain bacteria in the soil—denitrification—the nitrate molecule is utilized as an oxidizing agent, or as a source of oxygen, for the oxidation of available energy or food material. As a result of the chemical processes involved, the nitrogen part of the molecule goes into the air in the form of nitrogen gas.

Various workers have established that denitrification in soil is brought about by certain organisms when organic materials are present as energy sources and that denitrification is favored by anaerobic conditions—absence of molecular oxygen—such as occur in rather moist soils.

Denitrification has been generally considered to be of no economic importance in well aerated normal soils which contain moderate amounts of organic matter and are not too wet. Recent work, however, indicates that this view may not be entirely correct; that the denitrification rate may be affected more by the amounts of nitrate and decomposable organic materials in the soil than by the amount of oxygen gas.

Most denitrifying bacteria utilize organic materials as a source of energy. Some, however, obtain energy through the oxidation of inorganic substances such as sulfur and hydrogen.

Rather large amounts of sulfur are applied as a fertilizer to some California soils which contain insufficient quantities to meet plant growth requirements. Also, sulfur is used to acidify soils to be cropped to plants which prefer an acid reaction; to control certain plant diseases such as potato scab; to aid in the reclamation of alkali soils; and, because a neutral or slightly acid soil is sometimes thought to be a better medium for plant growth than one more alkaline in reaction. In addition, appreciable amounts of sulfur are added to the soil in the form of plant dust and spray residues.

Several investigators have noted a disappearance of nitrates in the soil after sulfur has been applied. This reduction could result from the denitrification process, from the utilization of the nitrate for cell synthesis by the bacteria oxidizing the sulfur, or both. To obtain more specific information on this point, a study was made which was designed to determine the effect of type of nitrogen fertilizer applied, and moisture content of the soil on disappearance of nitrates and actual loss of nitrogen from soil treated with elemental sulfur.

Meloland clay loam soil having a pH—relative acidity and alkalinity, with 7 as neutral and acidity indicated by lower numbers—of 8.0 was used in a laboratory study. Various nitrogen fertilizers were applied at the rate of 500 pounds nitrogen per acre. The original soil contained no ammonia nitrogen, about 30 ppm—parts per million—nitrate nitrogen, and 0.06% total nitrogen. The addition of the nitrogen fertilizers increased the total nitrogen to approximately 0.11%.

In the soil samples—which did not receive sulfur—added ammonia nitrogen was rather quickly oxidized to nitrate nitrogen. At all incubation periods—of 1, 3, 5, 10, and 20 weeks—and at all moisture contents in this series no loss of total nitrogen was detected.

In the soil to which sulfur was added, nitrate nitrogen quickly disappeared in the unfertilized soils and was reduced in those which received fertilizer nitrogen. As the moisture content of the soil increased, the magnitude of the nitrate reduction increased. After 20 weeks' incubation of the soil samples which received 2% sulfur and which were incubated at 90% of the moisture-holding capacity, no ammonia and no nitrate nitrogen were found regardless of the nitrogenous fertilizer added.

The total nitrogen determinations indicated that at low moisture level, the reduction in nitrate nitrogen did not represent an actual loss of nitrogen by denitrification but probably was due to the utilization for cell synthesis of some of the nitrate and ammonia nitrogen by the sulfur oxidizing bacteria. At higher moisture levels, however, actual losses of nitrogen occurred. At field capacity, about a third of the added nitrogen could not be accounted for, and at 90% of saturation, two-thirds or more of the added inorganic nitrogen was lost.

Less nitrogen disappeared from soils treated with ammonium hydroxide and dried blood than from the samples receiving the other nitrogen fertilizers. This was probably because denitrification of the nitrogen—added in the organic or ammonia form—would take place only after it is first oxidized to the nitrite or nitrate form. In the 1% sulfur series, and the ammonium hydroxide treatment, 154 ppm nitrate-nitrogen remained after 20 weeks' incubation. It appears that all the sulfur was oxidized before all the ammonia was transformed to the oxidized form, and therefore nitrate-nitrogen accumulated. In the 2% sulfur series, sufficient sulfur was apparently present after all the ammonia was oxidized to cause the disappearance of nitrate nitrogen from this soil.

The presence of sulfur in the soil tended to delay the oxidation of ammonia to nitrates.

Denitrification or a reduction in mineral nitrogen in conjunction with sulfur oxidation in soil will take place only when reduced forms of sulfur—such as elemental sulfur, hydrogen sulfide—are applied. It will not occur when oxidized forms of sulfur such as gypsum or sulfuric acid are added.

The studies indicated that at low moisture levels inorganic nitrogen is reduced or may be completely depleted by utilization of the nitrogen for cell synthesis by the organisms which oxidize the sulfur to sulfuric acid. The nitrogen in the nitrate molecules which is used as a source of oxygen is lost to the air in the form of nitrogen gas.

When sulfur is applied to soils, plants may temporarily suffer from lack of nitrogen if the amount of available or inorganic nitrogen is not sufficient to meet both the requirements of the organisms which oxidize the sulfur and the plants which are growing on the land.

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