"बेटी बचाओ, बेटी पढ़ाओ"

University Research Resource Journal
Jayoti Vidyapeeth Women's University, Jaipur
Volume – 1, Issue – 1 (Jan to March - 2018)
Page No: 01 - 06

ISSN: 2581 - 3730

## Sulphur Oxidizing Bacteria and Their Role in Plant Growth Promotions- A Review

Pratiksha Godara, Aditi Tripathi, Poorvija Pareek, Tripti Garg, Shrijana kumari

Department of Food and Biotechnology

Jayoti Vidhyapeeth Women's University, Jaipur

E-Mail Id: adititripathi@jvwu.ac.in

**Abstract**

The oxidation of sulphur is controlled by microorganisms, so it is the size, composition and activity of the microbial community dictates oxidation rates. Because oxidation is a biological process,so it is strongly affected by the factors which directly affects microbial activities such as temperature, water potential and aerations. Here we will also get to know what are the affects of sulphur on plants and how do they promote its growth. Sulfates taken up by the roots are the major sulfur source for growth, though it has to be reduced to sulfides before it is further metabolized. Root plastids contain all sulfate reduction enzymes, but the reduction of sulfate to sulfides and its subsequent incorporation into cysteine predominantly takes place in the shoot, in the chloroplasts. Majority of sulphur taken up by plant root in the form of sulphate (SO), which undergoes a series of transformation prior to its incorporation into the original 4 compounds. The soil microbial biomass is the key driving force behind all sulphur transformations. The biomass acts as both a source and sink for inorganic sulphate. They make available sulphate from element or any reduced forms of sulphur, through oxidation process in the soil. The role of chemolithotrophic bacteria of the genus Thiobacillus in this process is usually emphasized. Uses of sulphur oxidizers enhance the natural oxidation and speed up the production of sulphates.

**Keywords:** Sulphur, sulphur oxidizing bacteria, growth affects

**Introduction**

Sulphur is one of the essential plant nutrients and it contributes to yield and quality of crops. Sulphur occurs in wide variety of organic and inorganic combinations. The transfer of sulphur between organic and inorganic pool is entirely caused by activity of soil biota, particulary the soil microbial biomass, which has the greatest potential for both mineralization and also for subsequent transformation of oxidation state of sulphur. Thiobacilli plays an important in sulphur oxidation soil. For the good yield of crops sulphur is essential component, thus sulphur is important and also because of the of the excessive use of high analysis sulphur-free fertilizers, reduced industrial emissions of sulphur dioxides, the sulphur deficiency in soil is recognized, thus the increase in crop yield requires more sulphur.

A wide variety array of sulphur containing fertilizers is available to reduce sulphur deficiencies. Commercial availabilities of local soil condition and crop environment are the factors which totally decide which type of fertilizers should be applied. Elemental sulphur is the most concentrated form of sulphur which is used as fertilizer. It is not available until it is oxidized to SO-4. So it is not widely accepted. However the finely divided elemental sulphur is inconvenient for use and poses a fire hazard. But now some of the problems related with elemental sulphur are solved and many useful products are now available. Degradable soil products, liquid suspension and anhydrous ammonia-sulphur preparations are included in there elemental sulphur fertilizers. Oxidation of sulphur in soil The oxidation of s in soil is influenced by biological factors. Vegetation and local topography, and also biological processes such as oxidation, reduction, mineralization and volatization are the factors which are responsible for influencing the nature and quantities of various S pools in the soil. Plants obtain S primarily from soil as dissolved sulfate and, to a lesser extent, from the atmosphere by foliar absorption of SO2. Thus, the S cycle resembles the N cycle in having an important atmospheric component and having its soil content associated with organic matter; but it differs in that the ultimate natural source of plant available S is the weavathering of rock material [Bettany JR et.al.1973]. Soil surface contains more than 90% of the organic s constituents (Bettany JR1973, Biederbeck VO1978, Freney JR and Williams CH et.al.1983). The main inorganic form of sulphur are sulphides elemental sulphur, sulphites, thiosulphate, tetrathionate,and sulphate There are many microorganism which oxidize elemental sulphur in soil are divided into following groups:[a] Chemolithotrophs [b] Photoautotrophs [c] Heterotrophs. T he members of [a] and [c] are largely responsible for oxidizing sulphur in most aerobic soils.

## [A] Autotrophs

Bacteria important in soil system: A no. of chemolithotrophs are responsible for reducing inorganic sulphur compounds. Physiological characters of these bacteria are different. There are 2 metabolic types exist in chemolithotrophs group: The obligates which can only grow when grown with oxidizable sulphur compounds and heterotrophs which also use the mode of growth of chemolithotrophs (R.Vidyalaxmi, R.Pranthaman, and R.Bhakyaraj.2009).

### The role of thiobacilli in oxidation of sulphur in soil

The accumulations of sulphur compounds in soil occurs under natural conditions which indicates that these bacteria plays an important role in oxidation of sulphur and its compounds in soil [T.thioparus rapidly oxidizes sulphides to sulphates, but no intermediate sulphur accumulation has been observed](Wolf Vishnaic and Melvin Santer et.al.1957).The role of microorganisms in sulphur oxidation in atmospheric S polluted soil is largely overlooked, although it is clear that in such type of ecosystem the microbial oxidation of reduced S recieve (M.Wainwright et.al.1984).This review summarize our understanding of the factors which influence oxidation of S o fertilizers in soils, and discuss gaps in our knowledge.

### Other sulphur bacteria

Other bacteria may also oxidize sulphur compounds. The species of baggiatoa are the most important species in relation to sulphur oxidation in soil that participate in the sulphate oxidation in root zone of rice. Chromatium and Chlorobium are the type of phototrophic bacteria which plays an important role in sulphide oxidation in rice in soil, but not in aerobic agriculture soil (Kuenen,J.G. and R.F. Beudeker et.al.1982).

### Oxidation of inorganic sulphur in soil

1. ***Inorganic sulphur in soil***:

In most surface soils a very little reduced inorganic sulphur occurs under aerobic conditions. For example, in twenty-four Australian arable soils it was shown that on the average 1% of the total sulphur occurred in a form less oxidised than sulphate (Freney, J. R et.al.1960). On the other hand, under anaerobic conditions especially in tidal swamps and poorly drained paddy soil or subsoils considerable amount of sulphides can occur (Fleming, J. F., and L. T. Alexander, Hart, M.G.R et.al.1961).The accumulation of iron sulphide is the cause of deep colour of the shore of the Black Sea(Nelson, L.

E, Tisdale, S. L., and W. L. Nelson et.al.1964). It is well known that the main source of the soil's sulphur is sulphur which occursi in rocks and primary minerals, largely as mineral sulphides (Clarke, F.W. et.al.1924).Sulphate accounts for the major part of the inorganic sulphur in most soils. It can occur as water soluble sulphate, sulphate adsorbed on inorganic colloids and as sulphate.Appreciable amounts of soluble sulphate only occurs in subsoil horizons or in extremely arid conditions.

***2. Oxidation of sulphides:***

Under anaerobic conditions sulphide is formed due to reduction of sulphate , usually iron, and as this compound is insoluble so it will accumulate, common for low-lying land, paddy and delta soils during periods of water logging(Starkey, R.L et.al., 1950). MANDAL'S (Mandal, L.N et.al., 1961) results show that organic matter increases the accumulation of sulphide in waterlogged soil. When waterlogged soils or marine sediments are drained by the actions of Thiobacilli the sulphides present are normally oxidized to sulphate and other microorganisms and there will be an increase in acidity. By a purely chemical reaction the conversion of sulphide to sulphate can also occur.The pH of the soil may be reduced to values below 3 when the sulphur content of the soil is high (Hart1959, and Starkey et.al., 1950). The basic ferric sulphate produced from the oxidation of iron sulphide can actually be used for cemented together the soil materials (Vander Spek, J et.al.1950). Pyrite, FeS, has much more resistant towards oxidation than is FeS (Starkey, R. L et.al.1950) and considerable pyrite may be found in drained soils years after it has been reclaimed. It has been suggested (Harmsen, G. W et.al.,1954) that due to the high S/Fe ratio in the polysulphides, in arable soils developed from marine sediments in the Zulder-see area of Holland, and to the formation of insoluble iron phosphates the stability of iron polysulphides takes place

**4. The role of sulphur oxidizing bacteria in growth of plants**

Sulphur is present in various forms in the environment. Up to 95% of the total sulphur in the soil is associated with organic matter. Other sources of sulphur in soils are animal manure, irrigation water and, close to the coast or industrial areas, the atmosphere, where sulphurous gases such as sulphur dioxide and sulphur trioxide are dissolved in rainwater and washed into soil. The availability of sulphur from industrial emissions is relatively low in countries like Australia with legislation aimed at reducing industrial pollution. In the soil sulphur is present as organic sulphur compounds, sulphides (S-), elemental sulphur (S0), and sulphate (SO42-). Plants cannot absorb organic or elemental sulphur. For plants to be able to utilize sulphur from the soil it must be in the sulphate form. Organic sulphur and elemental sulphur are converted to the sulphate form in the soil. Sulphur can be removed from soil through uptake by plants, leaching through and out of the root zone by rainfall or irrigation, and by volatilisation. Sulphur can be transformed from one form to another in the soil through various biological and physical processes. This movement in and out of the soil between different chemical forms in the soil is known as the sulphur cycle.The sulphur cycle can be represented as shown below:

Use of sulphur oxidizing bacteria enhanced the rate of natural oxidation of sulphur and production of sulphates and makes them available to plants at their critical stages of growth, resulting in increasing plant yield (M.Wainwright et.al.1984). The biochemical oxidation of sulphur in alkaline calcareous soil produces $H_2SO_4$ which, in turn, decreases soil pH, solubilizes CaCO3more favorable conditions for plant growth including the availability of nutrients to plants (Abdou and A.S 2006,and El-Tarabily K.A., A.S. Abdou, E.S. Maher 2006 and M. Satoshi, Nemat, M.A.,AbdEl-Kader A.A.,M.Attia, A.K.Alva 2011,and Amal A. Mohamed, Wedad E.E. Eweda, A.M. Heggoand A. H. Enas et.al.2014) found that inoculation with sulphur oxidizing bacteria (SOB) increased height, yield and N uptake of onion plants when compared to those plants grown without inoculation. Moreover,( Mohsen, Kh 2012,and MohammedA.A., E.E.E. Wedad,A.M. Heggoand E.A. Hassan et.al.2014) showed that application of 200 kg sulphur plus Thiobacillus was the best treatment and can be recommended for onion.

**5. Sulphur for plant growth.**

Sowes its importance as a component of the (i) proteinaceous amino acids cysteine and methionine, (ii) non-protein amino acids including cystine, lanthionine, and ethionine (iii) tripeptide glutathione, and (iv)components including vitamins thiamine and biotin, phytochelatins, chlorophyll, coenzyme A, S-adenosyl-methionin and sulfolipids (Scherer, H et.al.2001). S plays critical structural roles in cells in the form of disulphide bonds in proteins, which is involved in enzyme regulation (redox control), and this provides protection from oxidative stress via glutathione, and its derivatives are involved in heavy metal stress mediation (Leustek, T., and Saito, K et.al.1999). In plants it also plays an important role in disease protection and defense response as a component of glucosinolates and allin compounds (Brader, G., Mikkelsen, M. D., Halkier 2006 and B. A., and Tapio Palva, and E, Jones, M. G., Hughes, J., Tregova 2014 and A., Milne, J., Tomsett, A. B., and Collin, H. A et.al.2004). Via deposition of elemental S in the xylem parenchyma fungal infection is prevented in various plant species (Cooper, R.M., and Williams, J. S et.al.2004). A zone of SO2−4 depletion is formed during S limitation when plant SO2−4 transporters are up-regulated for rapid SO2−4 up-take from the rhizosphere (Buchner, P., Takahashi, H., and Hawkensford, M.J et.al.2004). In this zone, mineralize organo-S is induced by bacterial desulfurization of organo-S, thus indirectly regulating plant S uptake (Kertesz, M. A., and Mirleau, P et.al.2004). However, reduction in root exudation (Alhendawi, R. A., Kirkby, E. A., and Pilbeam, D.J et.al.2005) or alteration of root exudatesis (Astolfi, S., Zuchi, S., Hubberten, H. M., Pinton, R., and Hoefgen, R et.al.2010) caused by S-deficiency in plants can result in influencing bacterial communities seeking exudates as source of carbon. Animal residues are particularly high in organo-S with sheep dung comprising ∼80% of S as sulfonates, and while SO2−4 is rapidly leached from soil, organo-S can persist for longer time periods (Haynes, R., and Williams, P et.al.1993).

**6. Removal of Sulphur**

The main ways sulphur is removed from pastures and soils is through leaching out of the root zone of plants and by ingestion of pasture by grazing animals. Leaching is the process whereby water, in the form of rainfall, flood waters or irrigation, is flushed through the root zone. This flushing process takes with it dissolved nutrients so that they become unavailable to plants through normal root uptake. Because sulphur in the sulphate form is very soluble it is easily leached out of the root zone under conditions of heavy rainfall or irrigation, and under conditions of moderate rainfall or irrigation in light soils. Studies in New Zealand have shown that 5-40kg S per hectare per year can be lost from grazed pastures through leaching. The advantage of adding elemental sulphur to the soil is that it acts as a 'slow release' source of sulphur to the plant as elemental sulphur is resistant to leaching and is oxidised slowly to sulphate as the plant requires it. Sulphur is also lost from the soil in plant and animal products.

**References**

**[1].** Abdou, A.S., 2006. Effect of applied elemental sulfur and sulfur-oxidizing bacteria (Parococcusversutus) into calcareous sandy soils on the availability of native and applied phosphorus and some micronutrients. World Congress of Soil Science, Philadelphia, Pennsylvania,USA. 9-15 Google scholar

[2]. Alhendawi, R. A., Kirkby, E. A., and Pilbeam, D. J. (2005). Evidence that sulfur deficiency enhances molybdenum transport in xylem sap of tomato plants. *J. Plant Nutr*. 28, 1347–1353. doi: 10.1081/PLN-200067449 Google scholar

[3]. Amal A. Mohamed, Wedad E.E. Eweda, A.M. Heggoand A. H. Enas, 2014. Effect of dual inoculation with arbuscular mycorrhizal fungi and sulphur-oxidising bacteria on onion (Allium cepaL.) and maize (Zea mays L.) grown in sandy soil under greenhouse conditions. Annals of Agric.Sci. 59:109–118. Google scholar

[4]. Astolfi, S., Zuchi, S., Hubberten, H. M., Pinton, R., and Hoefgen, R. (2010). Supply of sulphur to S-deficient young barley seedlings restores their capability to cope with iron shortage. *J. Exp. Bot.* 61, 799–806. doi: 10.1093/jxb/erp346 Google scholar

[5]. Bettany JR, Stewart JWB and Halstead EH (1973) Sulfur fractions and carbon, nitrogen and sulfur relationships in grassland, forest and associated transitional soils. Soil Sci. Soc. Am. Proc. 37: 915–918 Google scholar

[6]. Biederbeck VO (1978), Soil organic sulfur and fertility. Pages 273–310 In: Schnitzer M and Khan SU (ed) Soil organic matter, Elsevier Scientific Publ. Co., New York Google scholar

[7]. Clarke, F. W.: Data of geochemistry. U.S.Geol Surv. Bull. **770**,841p.1924. Google scholar

[8]. Brader, G., Mikkelsen, M. D., Halkier, B. A., and Tapio Palva, E. (2006). Altering glucosinolate profiles modulates disease resistance in plants. *Plant J*. 46, 758–767. doi: 10.1111/j.1365-313X.2006.02743.x Google scholar

[9]. Buchner, P., Takahashi, H., and Hawkesford, M. J. (2004). Plant sulphate transporters: co-ordination of uptake, intracellular and long-distance transport. *J. Exp. Bot.* 55, 1765–1773. doi: 10.1093/jxb/erh206 Google scholar

[10]. Cooper, R.M., and Williams, J. S. (2004). Elemental sulphur as an induced antifungal substance in plant defence. *J. Exp. Bot.* 55, 1947–1953. doi: 10.1093/jxb/erh179Google Scholar. Google scholar

[11]. El-Tarabily K.A., A.S. Abdou, E.S. Maher and M. Satoshi,2006. Isolation and characterization of sulfur-oxidizing bacteria, including strains of Rhizobium, from calcareous sandy soils and their effects on nutrient uptake and growth of maize (Zea mays L.).Aus. J. Agri. Res. 57(1):101-111 Google scholar

[12]. Fleming, J. F., and L. T. Alexander: Sulfur acidity in South Carolina tidal marsh soils. Soil Sci. Soc. Am. Proc. **25**, 94–95 (1961). Google scholar.

[13]. Freney, J. R.: The oxidation of cysteine to sulphate in soil. Australian J. Biol. Sci. **13**, 387–392 (1960). Google scholar

[14]. Freney JR and Williams CH (1983) The sulfur cycle in soil. Chapter 3 Pages 129–201 In: Ivanov MV and Freney JR (ed) The global biogeochemical sulfur cycle, SCOPE 19. John Wiley and Sons, New York Google scholar

[15]. Haynes, R., and Williams, P. (1993). Nutrient cycling and soil fertility in the grazed pasture ecosystem. *Adv. Agron.* 49, 119–199. doi: 10.1016/S0065-2113(08)60794-4 Google scholar

[16]. Hart, M.G.R.: Sulphur oxidation in tidal mangrove soils of Sierra Leone. Plant Soil.**11**, 215–236, (1959). Google scholar

[17]. Harmsen, G. W.: Observations on the formation and oxidation of pyrite in the soil. Plant Soil. **5**, 324–348 (1954). Google scholar.

[18]. Jones, M.G., Hughes, J., Tregova, A., Milne, J., Tomsett, A. B., and Collin, H. A. (2004). Biosynthesis of the flavor precursors of onion and garlic. *J. Exp. Bot.* 55, 1903–1918. doi:10.1093/jxb/erh138 Google scholar

[19]. Kertesz, M. A., and Mirleau, P. (2004). The role of microbes in plant sulphur supply. *J. Exp. Bot.* 55, 1939–1945. doi: 10.1093/jxb/erh176 Google scholar.

[20]. Kuenen, J.G. and R.F. Beudeker., 1982. Microbiology of Thiobacilli and other sulphur oxidising autotrophs mixotrophs and heterotrophs. In: Sulphur bacteria.J.P. Post Gate and D.P. Kelly (Eds.). University Press,Cambridge. pp: 473-497. Google scholar.

[21]. Leustek, T., and Saito, K. (1999). Sulfate transport and assimilation in plants. *Plant Physiol.* 120, 637–644. doi: 10.1104/pp.120.3.637 Google scholar

[22]. MohamedA.A., E.E.E. Wedad,A.M. Heggoand E.A. Hassan, 2014. Effect of dual inoculation with arbuscular mycorrhizal fungi and sulphur-oxidising bacteria on onion (Allium cepaL.) and maize (Zea maysL.) grown in sandy soil under greenhouse conditions. Annals of Agri. Sci., (59): 109–118 Google scholar

[23]. Mohsen, Kh, 2012. Effect of sulfur application rates on some quality traits and yield of Iranian Onion Varieties. J. Appl. Basic.Sci. 3(6):1215-1217. Google scholar

[24]. Mandal, L. N.: Transformation of iron and manganese in water-logged rice soils. Soil. Sci. **91**, 121–126 (1961). Google scholar

[25]. M.Wainwright Sulphur oxidation in soil, volume-37, 1984, page no.349-396. Google scholar

[26]. Nemat, M.A., AbdEl-KaderA.A., M.Attia and A.K.Alva, 2011. Effects ofnitrogen fertilization and soil inoculation of sulfur-oxidizing or Nitrogen-Fixing Bacteria on onion plant growth and yield.Inter. J. of Agro. Agro,316856,(6). http://dx.doi.org/10.1155/2011/316856. Google scholar

[27]. Nelson, L. E.: Status and transformation of sulfur in Mississippi soils. Soil Sci. **97**, 300–306 (1964). Google scholar

[28]. Quispel, A., G.W. Harmsen, and D. Otzen: Contribution to the chemical and bacteriological oxidation of pyrite in soil. Plant Soil **4**, 43–55 (1952). Google scholar.

[29]. R.Vidyalaksmi, R.Pranthaman and R. Bhakyaraj[2009] Sulphur oxidizing bacteria and pulse nutrition .World journal of agricultural science 5[3] page no. 270-278. Google scholar

[30]. Scherer, H. (2001). Sulphur in crop production—invited paper. *Eur. J. Agron.* 14, 81–111. doi: 10.1016/S1161-0301(00)00082-4 Google scholar