Advanced Science, Engineering and Medicine
Vol. 4, pp. 77–80, 2012
(www.aspbs.com/asem)

ARTICLE

Potentiality of *Thiobacillus* in Agricultural System

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Sulphur is extremely important to plant growth and soil health. Most agricultural soil contains some beneficial microorganisms belongs to genus *Thiobacillus*. These groups of bacterium play a significant role in the oxidization of sulphur, which might be responsible for the decreases the pH of the soil and solubilize the calcium carbonate in alkaline calcareous soils. Beside this it also makes the soil condition favorable for plant growth, and also helps the plants in nutrient absorption. In addition, *Thiobacillus* have the ability to reduce the disease severity and also protects the plants from various environmental stresses in the sustainable agricultural system.

KEYWORDS: Essential Mineral Nutrients, Phosphorus, Soil, Sulphur, *Thiobacillus*.

1. INTRODUCTION

The productive and sustainable agricultural system is desired for the well boon of the society and a keystone facet for growth and development of the country. The concept of limiting factor has been introduced to describe plant growth responses in respect to the altered resource availability.[1] Therefore, the absorption and accumulation of essential mineral nutrient is responsible for the increase in the productivity and quality of crop plants as foods and feeds.[2] The soils have the ability to direct the most essential nutrients preferred by plant. Thus, the minerals form a solid part of soil provide a mechanical support to the plants as well as for various types microorganisms lying in the same ecological niche.

The difference between rich fertile soil and poor infertile soil is essentially due to mineral composition of soil is now well recognized verity. There is no substitute for this problem even the highest amount of organic matter can't cope up with the concern mineral deficiency. The downward movement of minerals through soil is influenced by the quantity and pH of water. However, every mineral resource has different limiting factors which affect its availability in soil system. For example, phosphorus (P) uptake by plants is affected by both soil and plant factors. In general the soil phosphate availability is influenced by soil pH, $CaCO_3$ content, and total soluble salts concentration. The major chemical changes induced by root systems which might have influenced nutrient bioavailability of nutrients are:

(1) Soil pH change in rhizosphere,
(2) Increased levels of phosphatase for P mineralization
(3) Exudation of organic acids particularly with low molecular wet acids

The pH of the soil may directly influenced the equilibrium cone of nutrients in solid phase, resulted an increase in bioavailability nutrients particularly of P, Fe and Zn.[3,4] The mineral nutrients are available to plants in both ionic and molecular forms. Plant absorbs these minerals from the soil as single nutrient, which later combine with other elements to form nitrates, phosphates and sulphates. The root system of the plant absorb the nitrogen (N) as nitrates and nitrites; sulphur (S) as sulphate and phosphorus (P) as phosphates from the soil. The various types of absorbed nutrients were fixed into different forms by means of a complex process (i.e., phosphorus is fixed at higher pH and extreme low pH values). In this regard the *Thiobacillus* strains have adapted the better adaptability to solubilize the unavailable form of P into soluble form which enhanced the fertility and productivity of soil in agricultural system.[5]

2. CHARACTERISTIC OF *THIOBACILLUS*

Thiobacillus is acidophilic as well as thermophilic bacteria usually preferred to grow at the temperature between 45–50 °C. It has high comfort ability at pH of 1.5 to 2.5. It is

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Received: 11 November 2011
Revised/Accepted: 12 December 2011

colourless, rod shaped bacterium with polar flagella. The *Thiobacillus* genus has the unique ability to oxidize inorganic sulfur compounds as energy source. Furthermore, they are classified up to species level on the basis of their metabolism (i.e., the inorganic sulfur compound (s) utilized, the end products produced, adaptation to heterotrophy, and anaerobic growth in the presence of nitrate).[6]

Thiobacillus ferroxidans prefers the mine waste piles environment and increases the rate of pyrite oxidation in mine tailing and coal deposits. This bacterium posses an enzyme iron oxidase, which metabolize the metal ions such as ferrous ions and obtain nutrients by oxidizing iron and sulphur with O_2.

$$Fe^{2+} + \frac{1}{2}O_2 + 2H+ \rightarrow Fe^{3+} + H_2O$$

These groups of bacteria can oxidize elemental sulphur or ferrous sulphate by producing sulphuric acid that can solubilize the unavailable salts in the soils. The *T. thioparus* is active at higher pH while the *T. thiooxidans* is active at lower pH.[7,8]

$$MS + 2O_2 \xrightarrow{T.\ ferroxidans} M^{2+} + SO_4^{2-}$$

$$S + 1.5O_2 \xrightarrow{T.\ thiooxidans} H_2SO_4$$

This group of bacterium also have the potential to inhibit the process of bioacidification in the contaminated soil and sludge mixtures which causes significant impact on the mobility of metals, N and P.[9] It has several industrial applications and now widely used in the treatment of waste water of leather industry, modeling and analysis of bio-oxidation of gold, pyrite sulphur removal from lignite, bio-hydrometallurgical extraction, leaching of ZnS, oxidization of elemental sulphur in soils due to like due to presence of sulphur binding proteins on the surface of the flagella.

3. OCCURRENCE OF *THIOBACILLUS*

Starkey[10] have been discovered the thirteen species of *Thiobacillus* from the various ecological habitats. Out of 13 species, only five species (*T. thiooxidans, T. ferroxidans, T. thioparus, T. denitrificans* and *T. novellas*) have the ability to oxidise the sulphur in soil. Babana et al.[5] reported that out of 40 soil samples collected from two geographical zones only three samples showed the presence of *Thiobacillus* strains while out of 56 samples only five samples revealed the presence of *T. thioparus*.[11]

The *Thiobacillus* strains were also recovered from heavy metal contaminated soils,[12] whereas it has been also isolated from rhizosphere of paddy and pulse, sewage, biogas slurry, tannery effluent and mine soil.[8] Waksman and Jofee[13] showed the presence of *T. thiooxidans* from the pre-fertilized sulphur soil while 43 autotropic *Thiobacilli* strains from the agricultural land.[14] It has been also presumed that the acidophilic *Thiobacilli* (*T. thiooxidans*) were not common in occurrence but the neutrophilic *Thiobacilli* (*T. thioparus*) were found in almost 84% of the soils. The mesophilic and chemolithoautotropic sulphur oxidising bacterium, strain HT1 (*Halothiobacillus* spp.), was isolated from rice rhizosphere soil polluted by thiosulphate.[15]

4. SIGNIFICANCE OF *THIOBACILLUS* IN AGRICULTURAL SYSTEM

Sulphur is one of the essential nutrients which significantly affect the yield and quality of crops plants and soil health. Most of the agricultural soil contains the bacterium belongs to genus *Thiobacillus* which are responsible for the conversion of organic form of sulphur into inorganic forms (Fig. 1). It also plays an important role in the leaching and recovery of valuable metals from sulphide ores.[16,17] It is also evident from the results that *T. thioparus* and *T. thiooxidans* were responsible for the solubilization of rock phosphate and the decrease in the decrease in the sulphuric acid production in directly proportional with the concentration of rock phosphate in the growth medium.[5] The sulphuric acid production during sulphur oxidation is directly correlated with the reduce pH in the alkaline soils and may be responsible for the control of potato scrab and rot diseases caused by streptomyces. In the extremely acidic conditions, metals in contaminated soils are solubilize due to the destruction of soil metal complexes,[18] and the sulphur oxidizing bacteria have been employed for remediation of metal contaminated soil.[19] Thus it is evident from the previous reports that the formation of sulphate or sulphuric acid is advantageous in agricultural system because it makes alkali soils fit for cultivation of crop plants and also solubilize the inorganic salts containing plant nutrient which in turn increase the level of soluble phosphate, potassium, calcium and magnesium in the soil.[18,19] The plants utilize sulphur for their

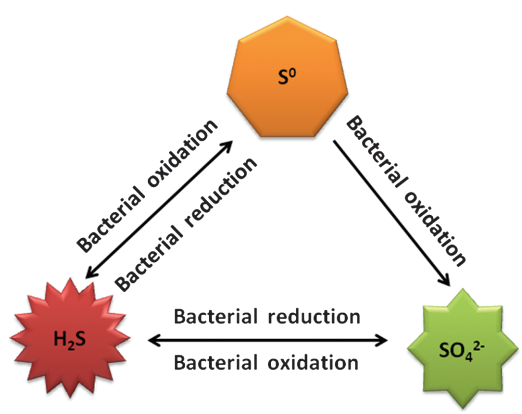

Fig. 1. Schematic diagram showing the potentiality of *Thiobacillus* strains.

metabolic activity which is derived by the transformation of elemental sulphur into sulphurated compounds (SO_4^{2-}) by the activity *Thiobacillus* isolates. The important genera of *Thiobacilli* responsible for this transformation are *T. thioparus*, *T. thiooxidans* and *T. ferroxidans* and these genera may also be influenced the availability of P to plants.[20, 21]

Naresh Kumar and Nagendran,[22] established relationship between growth, changes in pH, oxidation-reduction potential, sulphate production and metal solubilization of strain *Acidithiobacillus thiooxidans* with respect to time in sulphur medium and concluded that the growth of *A. thiooxidans* increased with the duration of time. A rapid drop in pH from 6.6 to 2 was recorded in the 1st week while, it goes beyond 1 in 18th day of the experiment. The sharp reduction in pH was observed during bioleaching, due to the production of sulfuric acid by *A. thiooxidans*. The bacteria oxidized elemental sulfur leading to soil acidification. The oxidation reduction potential increased rapidly between 6th and 16th days and it was found to be 612 mV at the end of the experiment due to oxidation of elemental sulphur to soluble sulphate form. A steep increase in sulphate production was also recorded during the 1–3 weeks of the experiment due to the active bacterial growth phase resulted in higher sulphur utilization while, in the last week of the experiment the rate of sulphur production was found to be lowered due to fall in *A. thiooxidans* biomass which is triggered by lowering pH. Similarly, the solubilization efficiency of Cr, Cd, Co and Zn was recorded as 88, 93, 92 and 97% respectively while the solubilization of heavy metal is lowered in the control treatment. Thus, it is obvious from the experiment that bioleaching results in unwanted dissolution of essential plant nutrients like N, P and K. However, Babana et al.,[5] have established the relation between the amounts of sulfuric acid produced, the number of bacterial cells and the quantity of P solubilize in the salts culture medium and concluded that increase in the number of bacterial cells increases the of production of sulfuric acid and the amount of P solubilize by the *Thiobacillus* AHB436 and AHB411 isolates (Figs. 2(A and B)).

Abd-Elfattah et al.[23] conducted an interesting experiment with *Thiobacillus* sp. in regulating metabolism in clay loam soil supplemented with elemental sulphur and reported that P uptake was up to 19.3% in soybean, when sulphur was used in combination with *T. thiooxidans* and a higher increase (9 times) was also recorded in case of extractable P compared untreated rock phosphate. Similarly, Aria et al.[24] conducted an experiment with *Thiobacillus* with sulphur and vermicompost on the water soluble P of hard rock phosphate and observed that water soluble P content was significantly higher in presence of *T. thiooxidans* compared to un treated control.

According to another report by Besharati et al.[25] evaluated the effect of biofertilizers produced from rock

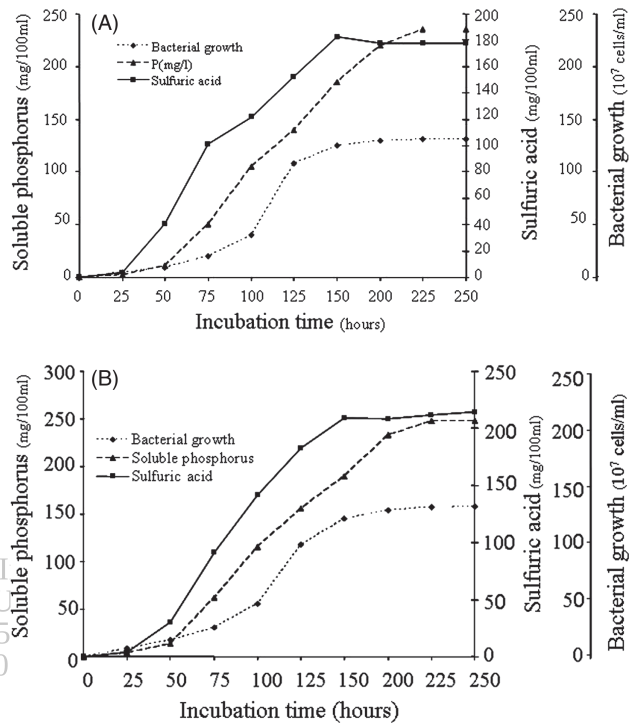

Fig. 2. Growth, sulfuric acid production and rock phosphate solubilization (A) by *Thiobacillus* strains AHB411 (B) by *Thiobacillus* strains AHB436.[5]

phosphate and sulphur inoculated with *Thiobacillus* in a calcareous soil with low level of available P with comparison to P soluble fertilizer (Triple super phosphate) and rock phosphate on corn shoot biomass, total P, Fe, and Zn accumulation and concluded that application of P caused an increase in total P in plant shoots and the results were pronounced when bio-fertilizers, rock phosphate with sulphur and *Thiobacillus* and triple super phosphate was used. The positive impact of the biofertilizers produced with rock phosphate plus sulphur inoculate with *Thiobacillus* on total P accumulated in shoots of corn holds these could be used as an alternative for partial or total substitution of soluble fertilizers. Similarly, El-Tarabily et al.[26] found that highest plant growth was recorded when sulfur-oxidizing bacteria were used in combination with sulfur and it is also responsible for the reduced soil pH, increased soil SO_4^{2-} level and the uptake of N, S, Fe, Mn, and Zn in maize plants. The beneficial effects of application of apatite along with sulfur and its oxidizing bacteria (*Thiobacillus*) to enhance nutrient availability (P, Fe, and Zn) and in turn uptake of these nutrients by plants has been showed repeatedly by many researchers.[27, 28]

5. CONCLUSION

The *Thiobacillus* strains present in the soil responsible for the oxidation of sulphur via production of sulphuric acid which might be responsible for the solubilization of the rock phosphate or significantly used for reclamination of alkali soil. However, these groups of bacterium also have the ability to produce an additive effect with the other microorganisms lying in the same ecological habit and also reduced the disease severity and also protect the plants from various environmental stress.

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