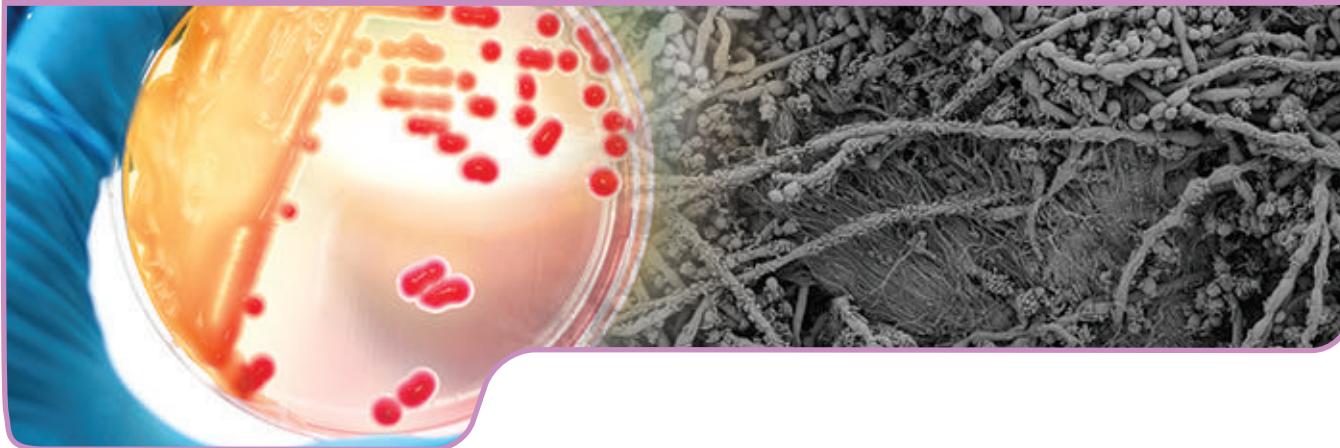


## Phosphorous solubilizing microbes: A promising approach to minimise triple super phosphate usage in rice cultivation

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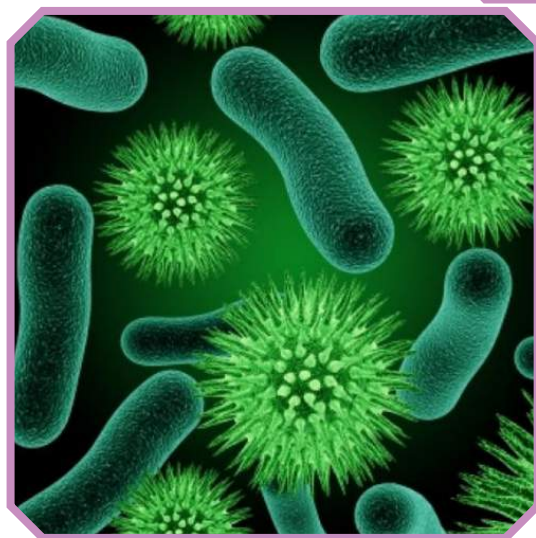
Phosphorus (P) is one of the major plant nutrients that lead to optimum crop growth and production. Even though most of the soils contain substantial P reserves, in most soils P remains insoluble, out of which only less than 10% is available for plants. Generally, available P concentrations are low in reddish-brown earth (RBE), which is the major soil group in the dry zone of Sri Lanka, where main agricultural production takes place. Previous studies revealed that the available P status of RBE varies from 1 to 87 mg/kg<sup>-1</sup>. The high P fixation in

soils leads to P deficiency in most Sri Lankan soils. Thus, the farmers use large quantities of P fertilisers to achieve the desired plant productivity.



more than 90 % of the P is water-soluble. Hence TSP could be rapidly absorbed by plants. Due to high water solubility, TSP is used as the P fertiliser for many crops, including annuals and perennials. Phosphate rock undergoes several acidulation processes in the TSP manufacturing process, leading to the addition of some trace elements into TSP. The trace element content of the TSP varies widely depending on the source of TSP.

It has been revealed that TSP applied rice fields in Sri Lanka have notable trace elements such as aluminium, chromium, nickel, cadmium, lead and uranium. According to literature, the Cd levels detected in TSP used in rice fields ranged from 23.50 to 71.74 mg/kg, which is higher than the maximum permissible levels of 10 µg g<sup>-1</sup> of the Sri Lanka Standards Institution (SLSI). Further, TSP contains a higher concentration of As (about 30 mg/ kg<sup>-1</sup>) than all the other P fertilisers used in Sri Lanka. The application of TSP increases the movement of Cd through food chains and can affect human health. The adverse effects of Cd on human health were first observed



Triple Super Phosphate (TSP) is widely used as a synthetic phosphate fertiliser in Sri Lanka (Figure 01). It is produced by the reaction of concentrated phosphoric acid with finely ground phosphate rock. Monocalcium phosphate is the active ingredient of TSP, and it is identical to superphosphate. It has a high P content, and

in subsistence rice farmers in Japan in the mid-1950s. They contracted a detrimental Cd poisoning (Itai-Itai disease) after consuming rice

and Fe and Al as impurities. The percentage of  $P_2O_5$  in ERP depends on the nature of the apatite crystals in the matrix, and the mining technique. The solubility of ERP is very low compared with other phosphorous fertilisers. Usually, citric acid solubility of ERP varies from 4 % to 6 % . Therefore, it is not recommended for short term crops or annual crops like rice and vegetables. ERP is generally used as a direct application for some perennial

since it causes only a meagre environmental impact on trace element accumulation. However, the application is limited due to its' low solubility. ERP is a good alternative for TSP if the solubility could be enhanced. In this regard, Phosphorus Solubilizing Microorganisms (PSMs) (Figure 03) play a vital role in solubilising phosphates in ERP.

The Phosphorous Solubilizing Microbes (PSMs) are a group of heterotrophic microorganisms capable of solubilising the inorganic forms of P by excreting organic acids. Naturally occurring PSMs were first discovered in 1903. They are highly concentrated in the rhizosphere, and they have higher metabolic activity than other microorganisms. Bacteria have a



**Figure 01: Triple Super Phosphate Fertilizer**

grown in soils that have been heavily polluted with Cd and other trace elements due to rapid industrialisation during the 1960s. The disease caused a softening of the bones and kidney failure. It is hypothesised that Cd accumulation in the human body causes Chronic Kidney Disease of Unknown etiology (CKDu), prevailing mainly in the dry and intermediate zones in Sri Lanka.



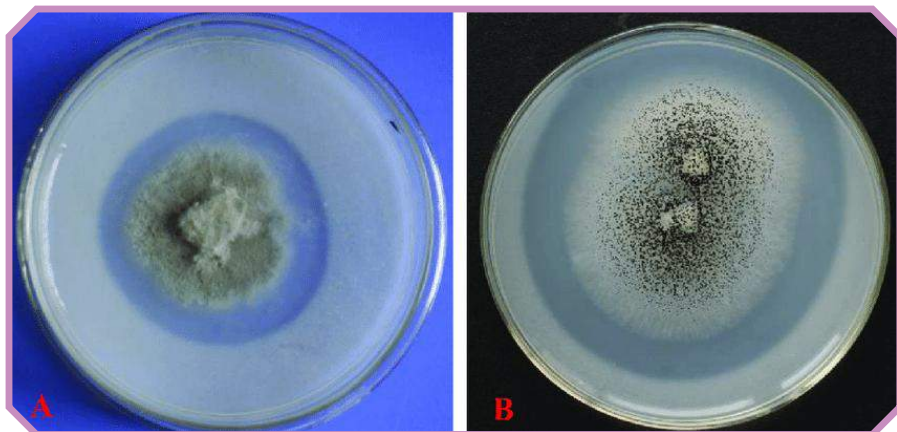
**Figure 02: Eppawala Rock Phosphate (ERP) Deposit**

Eppawala Rock Phosphate (ERP) is a cheap, phosphate-rich source used as a P fertiliser. The ERP deposit was discovered in 1971 by the Geological Survey Department of Sri Lanka (Figure 02). It is the largest rock phosphate deposit (approximately 40 million MT) in Sri Lanka, situated in Eppawala, in the North Central Province. It contains about 27 - 40 %  $P_2O_5$ ,

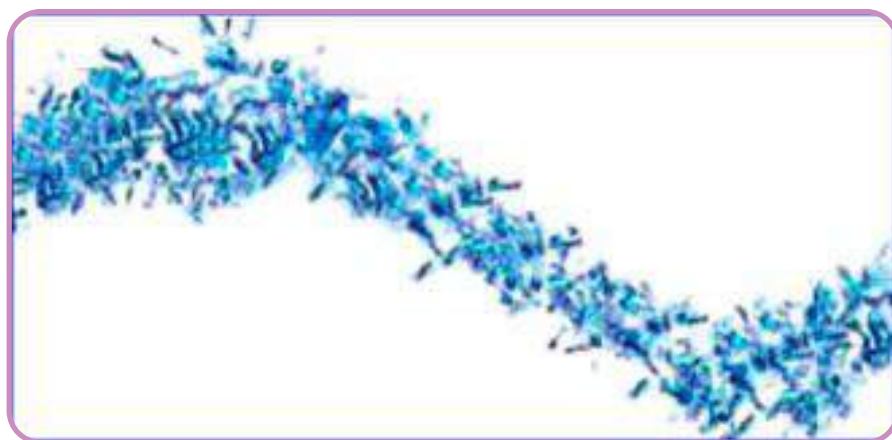
crops like tea, rubber and coconut, and some export agricultural crops grown in acidic soils. Further, ERP contains certain trace elements such as Cd ( $1.92 \mu\text{g g}^{-1}$ ) and As ( $8.56 \text{ mg/kg}^{-1}$ ) in minute amounts.

Eppawala Rock Phosphate shows an excellent potential to be used as a P fertiliser for annual crops

higher potential than fungi to P solubilisation. Ectorrhizospheric strains such as *Pseudomonas* and *Bacilli*, and endosymbiotic rhizobia in soil bacterial communities have been identified as effective phosphate solubilisers. Among fungi, *Achrothcium*, *Alternaria*, *Arthrobotrys*, *Aspergillus*, *Fusarium*, *Glomus*, *Micromonospora*, *Penicillium*,



**Figure 03: Phosphorous Solubilizing Microorganisms (PSMs)**



**Figure 04: Fungal Bacterial Biofilm**

*Saccharomyces* have been identified as effective P solubilisers. Moreover, approximately 20% of actinomycetes can solubilise P, including those in the genera *Actinomyces*, *Micromonospora*, and *Streptomyces*. Cyanobacteria have also been reported as P solubilisers. Solubilisation of P by PSMs is carried out through various mechanisms and microbial processes such as organic acid production and enzyme secretions.

Most of the PSM communities exist in the soil as biofilms. A biofilm consists of microbial cells (algal, fungal, bacterial and/or other microbial) and an extracellular biopolymer known as an extracellular polymeric substance (EPS) produced by microbes providing the structure

and protection to the community (Figure 04). These communities can be found in different environments. Biofilms can be developed *in vitro* as bio-fertilisers, known as Biofilmed Biofertilizers (BFBFs). Applying BFBFs in rice cultivation has significantly reduced chemical fertiliser usage by about 50 %. Also, the use of BFBFs has no known adverse environmental impacts, eventually leading to sustainable agricultural systems. National Institute of Fundamental Studies (NIFS) has developed four biofilm formulations with the potential to solubilise ERP, and preliminary studies have shown promising results.

The environmental impacts and associated health hazards due to

the heavy usage of TSP can be effectively minimized by developing approaches to replace TSP with ERP, which contains minute amounts of trace elements. For example, if ERP can be applied with a suitable microbial biofilm containing PSMs, it would provide an excellent alternative to minimise the TSP usage in rice cultivation.



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