Phosphorus Solubilizing Patterns of Different Phosphorus Sources in Rice Cultivation, Sri Lanka: A Case Study

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ABSTRACT

Biofilm enriched Eppawala Rock Phosphate (Biofilm-ERP) has been identified as a potential alternative for Triple Super Phosphate (TSP) application for rice cultivation in Anuradhapura, Sri Lanka. This is currently practiced in a few rice growing districts in Sri Lanka with the name of biofilm-ERP practice showing the most promising results in rice cultivation. This study was conducted to evaluate the Phosphorus (P) solubilizing patterns of biofilm-ERP over the Department of Agriculture (DOA) recommended full TSP dosage (2013)(CFE) for rice.

For the treatments, a modified chemical fertilizer (CFM) mixture was developed by replacing TSP in the DOA recommendation (CFE) from biofilm- ERP. Nitrogen (N) and potassium (K) levels were maintained as per the DOA recommendations and control was maintained without any fertilizer amendments. The experiment was arranged in a Completely Randomized Design (CRD) with three replicates. Soil pH, available N and P, organic matter (OM), and microbial biomass C were measured at the initially and end of the experiment. Solubilized P was recovered by leaching in two weekly intervals for up to three months. A significant effect was observed among the P solubilization patterns of treatments. Accordingly, the significantly ($p<0.05$) highest solubilized P was recorded with biofilm-ERP practice with a slightly increasing trend. Further, this pattern showed a slowly increasing trend over the solubilization period being caused by microbial assimilation of P and releasing of P into soil followed by microbial decomposition obviously with microbial biomass C measurements. The CFE solubilized the P also with a slightly increasing trend but it was significantly lower than the biofilm-ERP. In conclusion, biofilm-ERP was identified as the most outstanding P solubilizer with a sustained pattern for solubilized P. Hence, this biofilm-ERP would be an effective alternative for TSP for rice cultivation in near future. However, further field studies are needed for concrete findings.

KEYWORDS: *Biofilms, Biofilm-ERP, Eppawala rock phosphate, Phosphorus solubilization pattern, Triple super phosphate.*

Introduction

Rice (*Oryza sativa* L.) is one of the dominant food crops in the world. Rice occupies 34 % (0.77/ million ha) of lands from total cultivated lands in Sri Lanka (Senanayake and Premarathne, 2016). Improvement of rice productivity is one of the major targets in agriculture. In 1960, with the green revolution concept, enhanced chemical fertilizer application has been introduced as an option for rice yield improvement. Nitrogen (N), Phosphorous (P), and Potassium (K) are essential nutrients for rice cultivation. Most farmers use synthetic chemical fertilizers as a nutrient supplement in rice. Urea, Triple Super Phosphate (TSP), and Muriate of Potash (MOP) are commonly applied synthetic fertilizers in rice (Ekanayake, 2009). Triple Super Phosphate (TSP) is one of the most popular phosphorus fertilizers that become widely used in rice. It contains P nearly 43–48% as P_2O_5. Over

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90% of the total P in TSP is water-soluble, so it becomes rapidly available for plant uptake. Triple Super Phosphate has several agronomic advantages that made it such a popular P source for many years. But when considering environmental concerns TSP application is not recommended since it contains large amounts of As, and Cd like trace elements (Premaratna *et al.,* 2011). Eppawala Rock Phosphate (ERP) is a cheap, phosphate-rich source that contains a very minute amount of trace elements compared to the TSP. Average P_2O_5 content of ERP is nearly 30% (Dahanayake *et al*., 1995). But due to its low solubility, it is not recommended for direct application for short-term crops such as paddy. If the solubility of ERP is increased, it has a higher potential to use as a P source for annual crops. In this regard, microbial biofilms have been seen as the best resolution for enhancing the solubility of ERP (Mala *et al*.,2010). Furthermore, Jayaneththi *et al.* (2021) developed the biofilm- ERP which could be used as an alternative for TSP. This study was conducted to assess the P solubilization pattern of TSP and biofilm–ERP.

Methodology

A leaching column experiment was conducted at Soil and Water Science Laboratory, Faculty of Agriculture, Rajarata University of Sri Lanka. Paddy soil (Reddish Brown Earth and Low Humic Gley soils) was collected from a farmer's field, Puliyankulama, Anuradhapura. The soils belong to DL_{1b} agro-ecological region with an average annual temperature of 27^0C and average annual rainfall of 1368 mm. The soils at the experimental site were clayey in texture and classified as very poorly drained Reddish Brown Earth (Panabokke, 1996) that consisted of low organic matter (1.65%) in neutral soil reaction (pH= 7.3). It had a moderate level of available N. Available P content was close to critical or deficient level while K content was at sufficient level, but not in the optimum range for rice plant growth (Portch and Hunter, 2002). Soil microbial biomass was also very low initially. Exchangeable K was lower below the optimum level of 117-156 mg kg^{-1} for low land paddy cultivation in RBE-LHG catena.

Treatments

Biofilm and ERP were collected from authorized sellers. The biofilm was sprayed to ERP at the rate of 1.7 L 100 kg^{-1} to prepare the biofilm-enriched ERP (Jayaneththi *et al.*, 2021).

Department of Agriculture (DOA) recommended chemical fertilizer formulation (CF_E) (2013) for rice was modified by replacing TSP from biofilm ERP (CF_M). Following the DOA and National Institute of Fundamental Studies (NIFS) recommendations, the inorganic and biofilm- ERP treatments, (Table. 1) were added into columns. Treatments were arranged in a completely randomized design (CRD) with three replicates for each.

Table 1. Treatments used for the experiment

Treatments	
T1	DOA recommended fertilizer practice (2013) (CF_E) TSP (22 kg/ac), Urea (90 kg/ ac), MOP (24 kg/ac)
T2	Biofilm- ERP Practice (CF_M) [Biofilm –ERP (37 kg/ac), Urea (60 kg/ ac), MOP (16 kg/ac) + Biofilm- R (1 L/ac)]
T3	Control

Soil Analysis; Initial and end of the Experiment

Soil pH, available N, and P, exchangeable K, organic matter content, and microbial biomass C were measured initially and at the end of the experiment. Soil pH was determined by using soil: solution (distilled water) ratio of 1:2.5 (Anderson and Ingram, 1993). Available N content was determined by the Kjeldahl method (Stanford and Smith, 1972). Available P ($NaHCO_3$ extractable P) (Olsen, 1954), exchangeable K using atomic absorption spectroscopy, soil organic matter content was determined

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by the wet oxidation and colourimetric method (Baker, 1976). Soil microbial biomass carbon (Anderson and Domsch, 1972).

Leaching column experiment

Paddy soils and river sand were sieved (using a 2 mm) before mixing them thoroughly at a weight ratio of 1:1. The soil: sand mixture was sieved again using a 2 mm sieve before using them in the experiment. The leaching tubes (50 ml) were filled with the soil mixture and placed a glass wool pad (about ¼ - inch) on the surface of the soil to avoid dispersing soil. The initial weight of each tube was measured and recorded. Measured amounts of fertilizers were mixed thoroughly with 25 ml distilled water and added as treatments for each tube. Then the tubes were stoppered and incubated at 35^{o}C. Weights of leaching tubes were measured once in 3 days and maintained the initial weights with the help of distilled water. The leachates were collected in 2- weekly intervals (Stanford and Smith, 1972), and the available P contents of the leachates were measured using Olsen method (Olsen, 1954).

Statistical Analysis

The statistical analysis was performed using ANOVA (SAS institute) and mean separation was done using Turkey's HSD test. Microsoft Excel was used for the graphical analysis of data.

Results and Discussion

Phosphorous solubilizing patterns

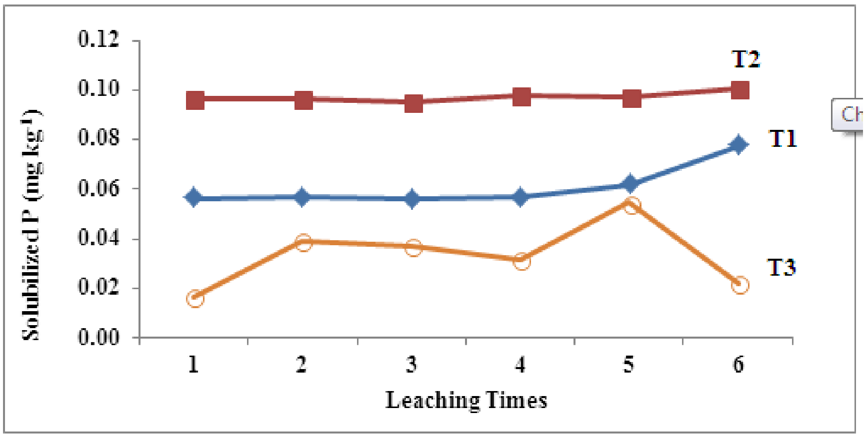

Fig:1. P solubilization patterns of treatments during three months of leaching tube experiment

Phosphorous solubilizing patterns of the treatments are illustrated in Fig: 1. Solubilization of P showed a slowly increasing trend for biofilm-ERP practice over the CF_E and control.

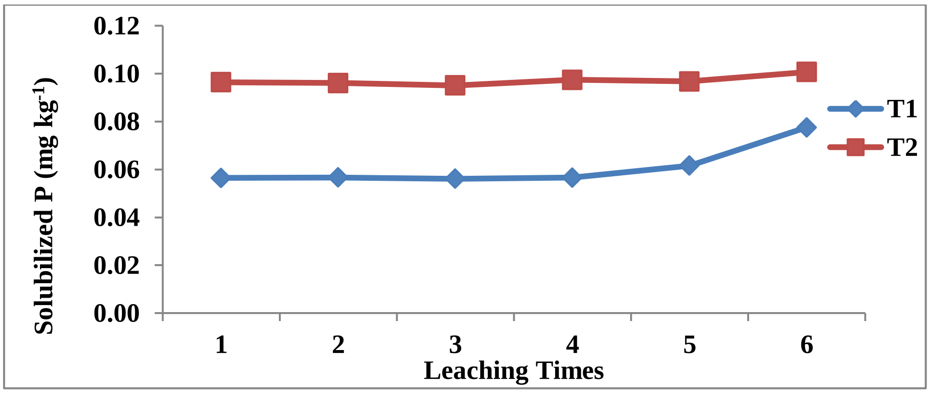

Fig: 2. T1 (CF_E) and T2 (biofilm-ERP practice) during three months of leaching tube experiment.

The pattern of CF_E results due to the rapid release of P from synthetic fertilizer sources. Nyambati and Opala (2014) noticed that the rapid releasing of nutrients from inorganic fertilizers into the soil undergoes a series of reactions that transform it to varying forms and reduce its availability to the plant.

In biofilm- ERP practice, a slightly increasing pattern was observed. The solubilized P is immobilized into microbial cells quantitatively decreasing the solubilized P (Pierzynski *et al.*,2005). Desorption of P by microbial decomposition following mineralization increase the soluble P up to a peak again (Jianbo Shen *et al*., 2011). This behavior is leading to an observable fluctuating pattern along with time.

The CF_E also solubilized P with a slightly increasing rate however it was quantitatively lower than the biofilm-ERP. This is probably due to the higher quantity of PSM in biofilms rather than CF_E. The PSM account for approximately 1% to 50% of P solubilization potential (Chen et al., 2006) and can mobilize insoluble soil P by the acidification of soil, the release of enzymes such as phosphatases and phytases (Jianbo Shen *et al.*,2011)

Soil pH, available N and P, exchangeable K, organic matter and biomass C

At the end of the three months of the leaching experiment, soil reactions taken place in all the treatments have been changed to slightly acidic. It may be due to organic acid production with the P solubilization process (Sharma *et al.,* 2013). Due to higher organic acid production with the P solubilization process biofilm applied treatment showed relatively higher acidic values compared to other chemical fertilizer added treatments and the control (Table 2).

Available N, P, and exchangeable K of the treatments recorded lower values compared to the initial soil analysis. During the three months, nutrients other than Available P were also solubilized due to the microbial activity (Table 2).

Table 2. Soil pH, available N and P, exchangeable K, organic matter and biomass C of treatments at the end of the leaching experiment.

Soil Property	T1	T2	T3
pH (H_2O)	5.57 ± 0.03^{c}	5.31 ± 0.03^{cd}	5.08 ± 0.03^{e}
Available P (mg kg^{-1})	11.74 ± 0.26^{c}	6.44 ± 0.46^{e}	11.99 ± 0.3^{b}
Available N (mg kg^{-1})	33.00 ± 0.89^{b}	32.67 ± 2.08^{b}	31.00 ± 2.00^{b}
Available K (mg kg^{-1})	26.95 ± 0.89^{b}	27.76 ± 0.32^{b}	26.90 ± 0.58^{b}
Organic matter (%)	$0.63 \pm 0,0^{cd}$	1.77 ± 0.01^{a}	1.63 ± 0.01^{b}
Biomass C (mg kg^{-1})	2.49 ± 0.12^{c}	3.81 ± 0.13^{a}	3.77 ± 0.11^{ab}

Means with the same letters in a row are not significantly different at $p < 0.05$ level according to the Tukey's mean comparison test.

Biofilm- ERP showed significantly *($p<0.05$)* higher organic matter content rather than the chemical fertilizer applied treatment (Table 2). Dissolved organic carbon (DOC) fluxes may be the main energy source for microorganisms as well as plays a critical role in the terrestrial ecosystem. Organic carbon can be mainly released by microbial decomposition processes and it might affect the organic matter fluxes in the soil (Silver *et al*., 2000).

Significantly *($p<0.05$)* higher soil microbial biomass is observed among biofilm- ERP over to CF_E (Table 2). The application of biofilm inocula enhances the content of beneficial microorganisms in the soil (Jaysinghaarchchi and Seneviratne, 2005). In (2004)Jayasinghaarachchi and Seneviratne revealed that the application of developed biofilm inoculants significantly increases nutrient solubilizing microorganisms in the soil. Introduced microbes and the subsequent emergence of cyanobacterial and fungal communities with the application of BFBFs could be the source for soil microbial biomass enhancement of the biofilms applied treatment.

Conclusion

The present investigation revealed P solubilization patterns of two P sources use currently in Sri Lankan paddy cultivation. ERP coupled with biofilm performed better than DOA recommended TSP dosage. The knowledge generated on the above patterns will be useful in the journey to sustainable and organic agriculture in Sri Lanka.

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