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Potential of Eppawala Rock Phosphate as a Phosphorus Fertilizer for Rice Cultivation in Acid Sulphate Soils in Matara District of Sri Lanka

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ABSTRACT: *Eppawala Rock Phosphate (ERP) is a phosphorus (P) resource in Sri Lanka containing about (28% to 42%) of P_2O_5 and an alternative for imported Triple Super Phosphate (TSP). Low water solubility of ERP has limited its use as a P fertilizer for rice. However, ERP could be used as a P source for rice grown in acidic soils due to its increased solubility under acidic conditions. This study was carried out during Yala 2015 and Maha 2015/16 seasons to investigate the potential of ERP as a source of P for paddy grown in acid sulphate soils in the Nilwala valley in Matara District. Six treatments including a control were arranged in a Randomized Complete Block Design with three replicates. Treatments were comprised of TSP as a basal application (recommendation of the Department of Agriculture) and by ERP as basal and split applications at rates of 25 and 50 kg P_2O_5 kg/ha respectively. Application of TSP resulted in a significantly higher plant height and dry matter production in comparison to the control. Application ERP at a rate of 25 P_2O_5 kg/ha as a split application and 50 P_2O_5 kg/ha (both split and single applications) showed a comparable plant height and an increase in dry matter production increment in comparison to the control. Significantly higher average panicle lengths and grain yields were observed in both TSP and ERP applied treatments in comparison to the control in Yala 2015. However, comparable increments were observed only in TSP applied treatment and ERP applications at a rate of 25 P_2O_5 kg/ha as a split application and 50 P_2O_5 kg/ha in Maha 2015/2016. Inconsistency of growth and yield performances of ERP treatments indicated the importance of long term experiments to determine suitable rates and methods of ERP application. This short-term study showed that ERP is a potential substitute for TSP for paddy grown in acid sulphate soils in Matara District.*

Keywords: *Acid sulphate soil, phosphorus, rock phosphate, rice*

INTRODUCTION

Rice (*Oryza sativa* L.**)** is the staple food of Sri Lankans and rice sector contributes to about 3.5% of the gross national production of the country. With the population growth rate of 0.9%, the estimated rice demand by the year 2018 would be 3.5 million tons. Therefore, the productivity of the cultivable rice lands of 1.1 million hectares has to be increased from 4.1 to 5.0 t/ha to fulfill the demand for rice. Implementation of corrective measures for soil

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related limitations such as soil fertility and nutritional constraints, iron toxicity, salinity and acidification would largely contribute to improve the productivity of paddy lands (Dhanapala, 2005).

Matara district contributes considerably to the production of rice in the low country wet zone (LCWZ) of Sri Lanka. The average yield of rice in LCWZ is 2-3 t/h and it is one of the responsible contributors for low national average rice yield (4.1 t/ha) of Sri Lanka (AgStat, 2014). In addition, the LCWZ is important as a buffer zone of rice cultivation with changing adverse climatic situations (Dhanapala, 2005). Therefore, efforts are to be made to increase the productivity of rice cultivating lands in LCWZ of Sri Lanka.

Nilwala is the major river in Matara district and cause frequent floods affecting the rice production while disturbing the livelihood of the people in Matara and Akuressa towns. Nilwala *ganga* (river) flood protection scheme (NGFPS) was introduced in 1980s to mitigate flooding in paddy growing areas in Matara district (GERSAR, 1981). One of the objectives of NGFPS project was to protect the paddy lands in Nilwala valley by constructing protection bunds along the river while improving the drainage. Deeper drainage network facilitated the evacuation of flood water in the paddy growing areas at lower streams of the river.

However, due to intensive drainage, sub soil of the area made up of pyrites layers exposed to free oxygen. This resulted in an oxidation of pyrite and ultimately acidifying the soil leading to development of acid sulphate conditions (Weerasinghe *et al.*,1996; 2000).

According to Pons (1973) and Fanning and Rabenhorst (2002), the acid sulphate soils (ASS) are identified by low pH (pH < 3.5) having sulfidic materials within top most 50 cm and/or a sulfuric horizon. These soils are typically low in fertility and especially poor in phosphorous nutrition. This situation limits the successful growth of many plants in acid sulfate soils and difficult to manage them for intensive cropping. However, rice is a tolerant important crop compared to other crops that can grow in such situations even though with some losses in yield.

Eppawala rock phosphate (ERP) is a locally available natural resource containing about 28% to 40% of P_2O_5 depending on the mining technique and the nature of apatite crystals in the matrix (Dahanayake, 1988). According to Pitawala *et al.* (2003) solubility of row ERP is very low. The reported approximate citric acid solubility varies from 4 to 6%. Although it is an important phosphorous fertilizer, its use is not recommended for annual crops like rice due less solubility in normal soil conditions. Present market price of triple super phosphate (TSP) and ERP are 55-60 and 16-17 Rs/kg, respectively. However, it is a good alternative for imported TSP if the solubility could be improved. According to the Le Van Can (1982) and Chien *et al*. (1990), the introduction of rock phosphate to rice cultivation in acid sulphate soils in Mekong delta, Vietnam was successful because of high agronomic effectiveness of rock phosphate under acid sulphate condition. Similarly, it is hypothesized that ERP too can be introduced as a phosphorous fertilizer source to acid sulphate soil condition in Matara district. Therefore, the objective of this study was to identify the suitable level of Eppawala Rock Phosphate to fulfil phosphorous requirement of rice under acid sulphate soil condition in Matara district.

MATERIALS AND METHODS

A field experiment was carried out in an acid sulphate soil in Malimbada Divisional Secretariat, Matara district during *Yala* 2015 and *Maha* 2015/16 seasons. Fields were ploughed, harrowed and leveled according to the recommendations of the Department of Agriculture. Rice variety At 362 which is the most popular rice variety in the area was used. Crop was established by broadcasting the water soaked pre-germinated seeds with the recommended rate. The experimental design was a Randomized Complete Block Design (RCBD), with three replicates. The plot size was 3 m x 6 m. The basic properties of the soil collected from experimental site at the commencement of the experiment are given in Table 1.

Table 1. Basic chemical characteristics of the soils of the experimental site

Soil characteristic	Value
pH (1:5 H_2O)	3.3
EC (1:1 H_2O) (dS/m)	0.64
Organic Carbon (%)	4.2
Olson's P (ppm)	8
Exchangeable K (ppm)	105

Treatments were consisted of Department of Agriculture recommended level of phosphorous (25 kg P_2O_5 /ha) provided by TSP alone as a basal application and ERP provided as both basal and split applications. The quantities of the ERP were calculated considering the P_2O_5 content in ERP as 28% (Dahanayake, 1988), and citric acid soluble P content as 7% (Pitawala *et al.*, 2003). Six treatments, i.e. no phosphorous control (T_1), basal application of 25 kg P_2O_5 /ha as TSP (T_2), basal application of 25 kg P_2O_5 /ha as ERP (T_3), basal application of 50 kg P_2O_5 /ha as ERP (T_4), split application of 25 kg P_2O_5 /ha as ERP, 50% at harrowing and the balance as a basal application (T_5), and 50 kg P_2O_5 /ha as ERP and applied as T_5 (T_6), were used in the experiment. The time gap between two split applications of ERP was 2 weeks. Each plot received N and K according to the Department of Agriculture recommendations. All cultural practices followed during the cropping seasons were in accordance with DoA recommendations. During the experiment soil samples were collected at the 50% flowering and at the end of the seasons. The pH levels of the soil were measured using glass electrode of a standard pH meter (potentiometry) and the electrical conductivity determined by conductometry. At plant maturity, the plant height and dried straw weight were measured. Panicle length and filled grain weight were measured as yield parameters. Collected data were subjected to ANOVA followed by performing post-hoc LSD test for differences between treatments using SPSS 18 statistical software.

RESULTS AND DISCUSSION

The surface soils of the experimental site was clay in texture and classified as very poorly drained Half-Bog (Panabokke and Alwis, 1972) that belongs to the soil taxonomic subgroup *Typic sulfaquents* (Senarath and Dissanayake, 1999).

During the experimental period the soil reaction of each plot was extremely acidic and a slight fluctuation was observed due to changes of field water levels (Figure 1). Similar observations were made by Perera, (1999).

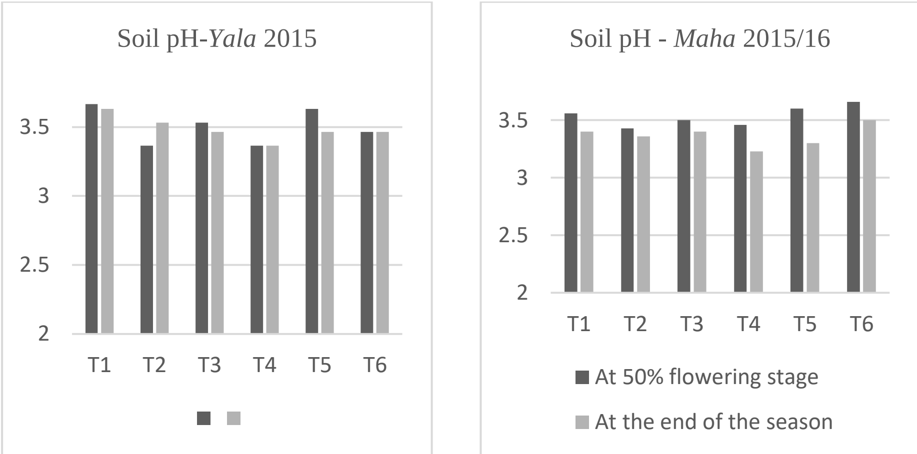

Figure 1. Variation in soil reaction (pH) among treatments at 50% flowering stage and at the end of the season

Better plant performances were observed in the *Maha* 2015/16 season than that in *Yala* 2015 in all treatments. In both seasons, the highest plant height at the time of harvesting was recorded in plants that received DoA recommendation (Table 2). The plant height in *Maha* 2015/16 was 85.9 cm in T_2 and was comparable (85.8 cm) with the split application of 25 kg P_2O_5 /ha as ERP (T_5).

Table 2. Growth parameters of rice in different phosphorous treatments

Treatment	Plant height at harvesting (cm)		Dry straw content kg/ha	
	***Yala* 2015**	***Maha* 2015/16**	***Yala* 2015**	***Maha* 2015/16**
T_1	70.1 ^{b}	80.8 ^{b}	2149.0 ^{b}	3199.5^{c}
T_2	76.8 ^{a}	85.9 ^{a}	3635.4 ^{a}	4507.4^{a}
T_3	73.2 ^{ab}	81.2 ^{ab}	3186.1 ^{a}	3634.6^{bc}
T_4	72.9 ^{ab}	82.9 ^{ab}	3562.4 ^{a}	4337.1^{ab}
T_5	71.3 ^{b}	85.8 ^{a}	3504.1 ^{a}	3915.0^{abc}
T_6	72.2 ^{b}	82.9 ^{ab}	3816.9 ^{a}	3746.8^{abc}
LSD	4.02	3.27	834.85	767.4

Means followed by the same superscript are not significantly different at P≤0.05 in a column, LSD- least significant different.

Plant height at the time of harvesting in treatments where ERP was applied only as a basal dressing, T_3 and T_4, are comparable with plant heights in TSP treatment. The lowest plant height was observed in the control treatment (T_1) in both seasons. This confirms that these soils are low in available P and needs to be supplied for better growth of rice under acid sulphate condition. In addition, Wickramasinghe *et al.,* (2009) reported that high P requirements of improved rice varieties for better growth.

Straw production data are given in the Table 2. Phosphorus application has produced significantly high straw yields in *Yala* 2015. The highest straw (3816.9 kg/ha) production was recorded in the treatment T_6, in which split application of ERP at the rate of 50 kg P_2O_5 /ha was practiced. This was followed by the straw yields of T_2, T_4, T_5 and T_3, However, significant differences of average straw yields were not observed between P applied treatments.

In *Maha* 2015/16, the highest dry weight of straw was observed in T_2. This was followed by treatment T_4, which was treated with 50 kg P_2O_5 /ha (200%) of phosphorous by ERP as basal. Although, ERP applied T_3, T_5 and T_6 showed higher straw yields these averages were not significantly different to other treatments including the control. These results showed potential of using ERP for rice as a Phosphorous fertilizer without affecting biomass production in acid sulphate soils in Matara district.

Measurements of yield parameters are presented in the Table 3. In both seasons, the lowest panicle length and filled grain yield were recorded with no P application (control (T_1)). They were significantly different from P added treatments, irrespective of source or method of P application.

Table 3. Effect of different phosphorous treatments on yield parameters of rice

Treatment	**Panicle length (cm)**		**Filled grain yield kg/ha**	
	***Yala* 2015**	***Maha* 2015/16**	***Yala* 2015**	***Maha* 2015/16**
T_1	39.8^{b}	45.3^{c}	1126.0^{b}	3282.5^{b}
T_2	44.1^{a}	51.4^{a}	1882.7^{a}	4680.2^{a}
T_3	45.2^{a}	51.5^{a}	1732.3^{a}	4234.2^{ab}
T_4	46.8^{a}	48.0^{bc}	1887.8^{a}	4441.7^{ab}
T_5	45.5^{a}	49.6^{ab}	1711.0^{a}	4662.8^{a}
T_6	43.9^{a}	51.0^{a}	1899.8^{a}	4637.5^{a}
LSD	4.04	2.87	452.36	1172.3

Means followed by the same superscripts are not significantly different at P=0.05 in a column, LSD- least significant different, CV- Co-efficient of variance

The filled grain yields in all P added treatments were not statistically different. In *Yala* 2015 the maximum filled grain yield (1899.8 kg/ha) was observed in T6 with the split application of 50 kg of P_2O_5/ha as ERP. Department of Agriculture recommended basal application of 25 kg of P_2O_5/ha as TSP (T2) gave the maximum yield (4680.2 kg/ha) in *Maha* 2015/16. The split applications of ERP (T5 and T6) also recorded yields that are comparable with T2. Contrasting, in *Maha* 2015/16 control plots recorded a comparable yield with T_3 and T_4 that ERP applied as a basal dressing. This may be due to changes of water regime in *Maha* season. In addition, Chien *et al.,* (1990) reported that agronomic effectiveness of rock phosphate was increased with low pH and high P-fixing acid sulphate soils in Vietnam. These results suggested that split application of ERP can substitute TSP application in acid sulphate soils. Results of this study suggested that split application of 50 kg P_2O_5 /ha (200% of the DOA recommendation) of P by ERP at harrowing and as a basal dressing.

CONCLUSIONS

This experiment revealed the potential of use of ERP as a replacement for TSP in an acid sulphate soils in Matara district. The results suggested that 176 kg of ERP/ha, or 50 kg P_2O_5 /ha could be used as a substitute for TSP in split application of 88 kg/ha at the time of harrowing and 88kg/ha as a basal. This short-term study revealed that comparable yields can be obtained both in *Maha* and *Yala* seasons by substituting TSP with ERP. However, long-term experimental results are required to develop more reliable recommendations and set accurate yield targets.

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