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Short-term Influence of Organic Matter and Saline Water on Inorganic Soil Phosphorus Transformation in Barisal and Dumuria Soil Series of Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. Author MZK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors MAI and MSA reviewed the study design and all drafts of the manuscript. Authors MZK and RH undertook the statistical analysis of the data collected. Author MZK managed the literature searches and reference-citations. Finally, all the authors read and approved the final manuscript.

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ABSTRACT

A laboratory incubation experiment was carried out to investigate the influence of soil salinity and organic matter on inorganic phosphorus transformation with times in two different soil series such as Barisal and Dumuria located in Ganges Tidal Floodplain sites of Bangladesh. Two representative soil samples were collected from surface soil (0-15 cm) with composite sampling. The salinity and organic matter treatments were 4 dS m^{-1} and 5 t ha^{-1} (decomposed cow dung) with three replications. The treated soils were then incubated in the laboratory at field capacity moisture condition. To determine the transformation of different forms of inorganic P, sampling was done for 0, 7, 15 and 30 days. Different forms of inorganic P such as soluble and exchangeable phosphorus (SE-P), iron and aluminium bound phosphorus (Fe and Al-P), calcium bound phosphorus (Ca-P) and residual phosphorus (RE-P) were determined at different days of incubation. For Barisal soil series, the sequence of different forms of inorganic P was Ca-P>RE-P>Fe and Al-P>SE-P

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according to their amount. For Dumuria soil series, the sequence was Ca-P>RE-P>Fe and Al-P>SE-P, respectively. The sequence clearly indicates that the soluble and exchangeable P increases with time due to a combination of salinity and decomposed organic matter which increases the uptake of P and ultimately increases the yield. The changes were statistically significant (*P* < 0.001) in the case of all three soils.

Keywords: Phosphorus transformation; soil series; salinity; cropping pattern; decomposed organic matter; yield.

1. INTRODUCTION

Phosphorus (P) is an important naturally occurring element in the environment that can be found in all living organisms as well as in water and soils. It is a component of key molecules such as nucleic acids, phospholipids, and adenosine triphosphate (ATP). Phosphorus is also a critical element in natural and agricultural ecosystems throughout the world [1], as its limited availability is often the main constraint for plant growth in highly weathered soils of the tropics [2]. Consequently, plants and animals cannot grow without a steady supply of this nutrient [3]. The efficiency of applied P fertilisers to soils is low [4] because fast adsorption and/or precipitation reactions occur due to the existence of clay minerals and to the presence of soil components such as Ca, Al and Fe [5].

However, organic manure additions also result in the direct addition of P as well as acceleration of native P solubilization by the release of weak organic acids. The ability of the soil to release P into solution varies with soil type [6], and much work has done in this area, but few studies have looked at release kinetics within the same soil over a range of organic manures. This is especially important for calcareous soils such as in arid and semi-arid regions because in these areas the crop uptake efficiency of fertiliser P is low. This calls for increasing the use efficiency of phosphate fertilisers through various means [7]. In recent years, the application of organic residues with a high organic matter content, such as animal manures, has become a common environmental practice for maintaining soil organic matter and supplying plant nutrients [8].

Soil salinisation is one of the significant factors that contribute to land degradation and decrease in crop yield [9]. Salt-affected soils are characterised by high concentrations of soluble salts and low organic matter and nitrogen content [10]. The negative effects of salinisation are intensified by the low levels of soil organic matter [11] and decreasing stability of soil structure, i.e. the tendency to slake, disperse and swell under specific conditions [12].

The inorganic P in soils have been classified into soluble phosphate (SE-P), aluminium phosphates (Al-P), iron phosphates (Fe-P), residual soluble phosphates (RE-P) and calcium phosphates (Ca-P) [13]. The release of organically and inorganically bound nutrients like P, which can then be utilised by plants, is particularly important in agriculture [14]. Phosphorus in adsorbed and/or mineral form is often coated (occluded) by relatively insoluble oxides and hydroxides of Fe and Al. The occluded P is called RE-P because strong reducing agents are required to dissolve the coating occluding the P. These phosphate fractions occur in all soils, but differ in proportion according to soil characteristics. Strong acid soils, usually highly weathered, are dominant in Al-P, Fe-P and RE-P. Neutral and slightly acid soils usually contain all five fractions in comparable amounts. Alkaline and calcareous soils are often dominant in Calcium- Phosphate. The increase in any one fraction occurs at the expense of other inorganic fractions [15]. Therefore, the Objectives of this present research work was to investigate the influence of organic matter and saline water on inorganic P transformation in Dumuria and Barisal soil series.

2. MATERIALS AND METHODS

A laboratory incubation experiment with two representative soil (Dumuria and Barisal) series of Ganges Tidal Floodplain was carried out to determine the effect of saline water and organic matter treatments on the transformation of inorganic phosphorus at field capacity moisture condition with time.

2.1 General Information about Sampling Sites

Two soil samples were collected from the agricultural field at Gutudia of Dumuria Upazila. Dumuria soil series was calcareous in nature and

Barisal series was non-calcareous. The land type is medium high land. The lands are mainly used for rice cultivation. Aus, T-Amon and IRRI are cultivated in the lands, and sometimes *Zea mays* and mung are also cultivated here. The land use pattern was Rice-*Zeya mays*-Mung in the sample site.

2.1.1 Collection and preparation of soil samples

All the soils were collected at a depth of 0-15 cm on the basis of composite sampling. The collected soil samples were air-dried ground and sieved through a 2 mm sieve. The samples were then preserved for analysis.

2.2 Physical and Chemical Properties of Selected Soil Samples

Measurements of selected physical and chemical properties of the soils were carried out in triplicate according to conventional methods. Some general properties of the soil series are presented in Table 1.

2.3 Incubation Experiment

The two-hundred-gram soil was incubated in one kg capacity plastic container after application the four treatments with three replications. The pots were covered with parafilm to prevent the loss of water through evaporation. The oven dry weight of the soil was determined gravimetrically. To determine the transformation of different forms of inorganic phosphorus to effect on saline water, organic matter (decomposed) and saline water plus organic matter (decomposed cow dung). Sampling was done for 0, 7, 15 and 30 days from the incubated soils. Treatment details are presented in Table 2.

2.4 Fractionation of Inorganic Phosphorus

The phosphorus fractions were extracted stepwise by wet chemical sequential extraction scheme by using the modified version of the Hedley et al. [16] procedure as the modified procedure is outlined by Alverez-Rogel et al. [17]. One gram of each soil sample was taken into a centrifuge tube, and different fractions were extracted by the sequential fractionation procedure. SE-P were extracted from each soil samples with 40 ml 2 M KCl for 2 hours at room temperature with continuous agitation, Fe and Al-P were extracted from the residue of the first fraction of each soil samples with 40 ml 0.1 M NaOH for 17 hours with continuous agitation, Calcium bound P were extracted from the residue of the second fraction of each soil samples with 40 ml 0.5 M HCl for 24 hours with continuous agitation and RE-P were extracted from the last fraction of each soil samples from digestion with 5:2 mixtures of concentrated HNO_3 and $HClO_4$.

2.5 Phosphorous Determination from the Extract

The concentration of Soluble and exchangeable P, Fe and Al bound P, Ca-bound P and Residual P were determined by Molybdophosphoric blue colour method in the sulfuric acid system [18].

2.6 Statistical Analysis

Analysis of variance (ANOVA) was calculated by using PROC GLM [19] to determine the effects of saline water and organic matter. Correlation coefficients between different parameters were calculated by using MS Excel Computer Package, Version 13.0.

Table 1. Some general properties of the soil series

Soil series	EC ($dS\ m^{-1}$)	pH	Total P (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class
Barisal	8.24	6.87	0.068	8	41	51	Silty clay
Dumuria	6.98	7.45	0.07	12	53	35	Clay

Table 2. Treatment of the experiment

Treatment	Description
T_0	Distilled water (control)
T_1	Saline water (4 $dS\ m^{-1}$)
T_2	Organic matter (decomposed cow dung 5 $t\ ha^{-1}$)
T_3	Saline water (4 $dS\ m^{-1}$) plus organic matter (decomposed cow dung 5 $t\ ha^{-1}$)

3. RESULTS AND DISCUSSION

3.1 Soluble and Exchangeable Phosphorus (SE-P)

In Barisal soil series (Fig. 1), SE-P slightly increased from 0 days to 7 days for all treatments and then rapidly decreased from 7 days to 15 days for all treatments except treatment T_0. The SE-P content was gradually increased up to 30 days with T_0 treatment. The highest value was obtained (12.63 µg g^{-1}) for treatment saline water (T_2) at 30 days. The lowest value was obtained (1.99 µg g^{-1}) for treatment organic matter (T_1) at 15 days. SE-P was similarly changed from 0 days to 30 days. The change of SE-P of Barisal soil series was positive with treatments and time and the change was statistically significant ($P < 0.001$).

For Dumuria soil series (Fig. 2), the SE-P increased slightly from 0 days to 7 days for all treatments and rapidly decreased up to 15 days. The highest value was obtained (12.63 µg g^{-1}) up to 30 days for the treatment saline water (T_2). The SE-P was exponentially increased from 15 to 30 days with all the treatments. The lowest value was obtained (1.63 µg g^{-1}) up to 15 days with the treatment of organic matter (T_1). The SE-P was similarly changed from 0 to 30 days with all the treatments. The change of SE-P in Dumuria soil series with treatments and time was statistically significant ($P < 0.001$).

Tomar et al. [20] reported that in calcareous soil soluble and exchangeable phosphorus increased after 4 days of incubation at field capacity moisture and decreased at 60 days but the values remain positive. The very small amount of phosphorus present in the form of soluble and exchangeable phosphorus. Rabbi et al. [21] reported that after 15 days available P increased sharply in non-calcareous soil but in calcareous soil, this change was barely discernable. Kothandaraman and Krishnamoorthy [22] stated that soluble and loosely bound P ranges from 0 to 79 µg g^{-1}. Alluvial soils were high followed by red soils (11 µg g^{-1}) while black and laterite soils were very low in this fraction. The values obtained in the present study revealed that soils showed variation in their soluble and exchangeable phosphorus contents and values of the Dumuria and Barisal series ranged from 0.71 to 1.41 µg g^{-1} at the beginning of the experiment. Rabbi et al. [21] also reported that in the calcareous soil after 30 days, available Phosphorus increased sharply and tended to be levelled off after 60 days of incubation.

3.2 Iron and Aluminium Bound Phosphorus (Fe and Al-P)

In Barisal soil series (Fig. 3), Fe and Al-P slightly increased from 0 days to 7 days for all treatments and then rapidly increased from 7 days to 15 days for all treatments. The highest value was obtained (122.63 µg g^{-1}) for treatment saline water plus organic matter (T_3) at 15 days. Fe and Al-P exponential decreased from 15 days to 30 days for all treatments. The lowest value was obtained (21.63 µg g^{-1}) for treatment organic matter (T_1) at 30 days. Fe and Al-P were similarly changed from 0 days to 30 days. The result of increased of Fe and Al-P may due to the low pH or acidic nature of the soil. The result of decreased of Fe and Al-P may be due to the high pH or alkaline nature of soil with the time of incubation. The change of Fe and Al-P of Barisal soil series with treatments and time was statistically significant ($P < 0.001$).

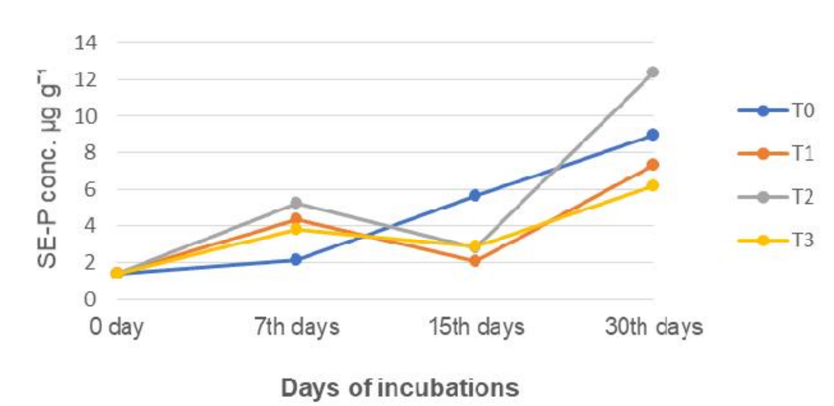

Fig. 1. Change in SE-P content with time (Barisal soil series)

For Dumuria soil series (Fig. 4), the Fe and Al-P increased slightly from 0 days to 7 days for all treatments and rapidly increased up to 15 days. The highest value was obtained (115.63 µg g^{-1}) up to 15 days for the treatment saline water (T_2). The Fe and Al-P were exponentially decreased from 15 to 30 days with all the treatments. The lowest value was obtained (40.00 µg g^{-1}) up to 30 days with the treatment of organic matter (T_1). change of Fe and Al-P of Dumuria soil series with treatments and time was statistically significant ($P > 0.001$).

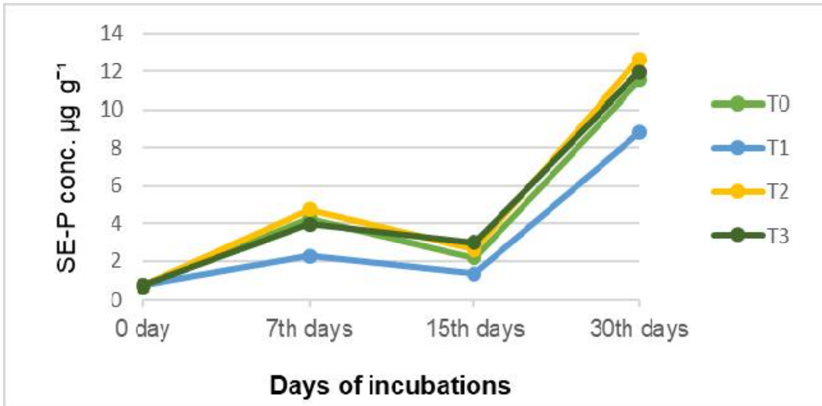

Fig. 2. Change in SE-P content with time (Dumuria soil series)

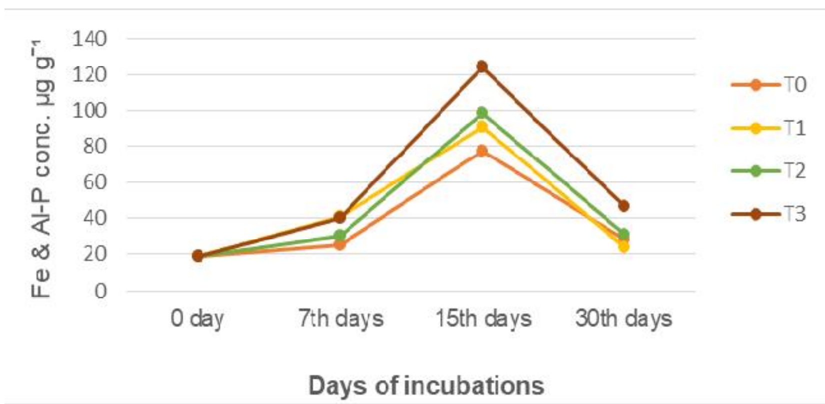

Fig. 3. Change in Fe and Al-P content with time (Barisal soil series)

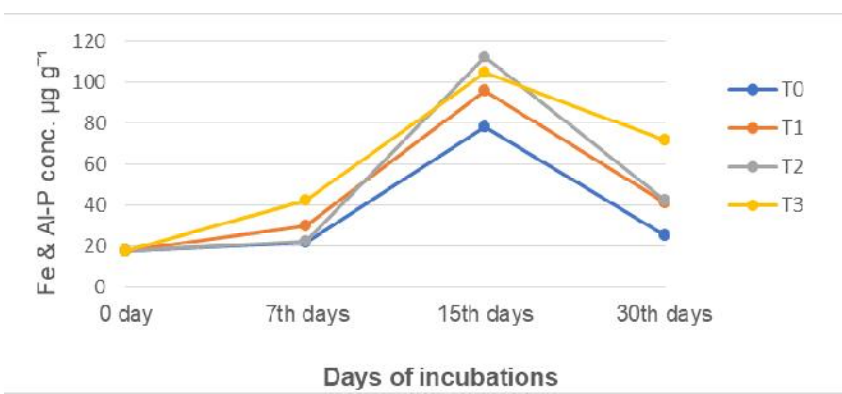

Fig. 4. Change in Fe and Al-P content with time (Dumuria soil series)

Islam and Khan [23] found that iron and aluminium bound phosphorus increased with time up to two weeks at field capacity moisture condition due to increased acidity of the soil. The result obtained of the present study was the same as Islam and Khan observation. The decrease of iron and aluminium bound phosphorus might be due to the high content of total as well as free iron and aluminium oxides in the soil, which might have played a major role in the fixation of phosphorus. De Datta et al. [24] reported that phosphorus in all forms exists in all soils, but iron and aluminium bound phosphorus are most abundant in acids soils. The increase or decrease of iron and aluminium bound phosphorus indicated that the increase or decrease of other fraction of phosphorus.

3.3 Calcium Bound Phosphate (Ca-P)

In Barisal soil series (Fig. 5), the Ca-P contents slightly increased up to 7 days of incubation with saline water and organic matter but the Ca-P contents were decreased with the organic matter plus saline water. The Ca-P was rapidly decreased up to 15 days with saline water (T_2). The Ca-P content was a similar change up to 30 days with organic matter treatment. But the Ca-P content was increased rapidly up to 15 days with organic matter plus saline water (T_3) treatment. The highest value of Ca-P (195.63 µg g^{-1}) was obtained with saline water (T_2) treatment in this soil at the end of 7 days of incubation. The lowest Ca-P content (110.00 µg g^{-1}) was observed in the Barisal soil series at the end of 7 days with saline water plus organic matter (T_3) treatments. The Ca-P content was insignificantly changed with all the treatments from 0 to 30 days.

Dumuria soil series (Fig. 6), the Ca-P content with saline water and organic matter treatments showed not a similar trend of changes throughout the experiment. The Ca-P contents slightly decreased up to 7 days of incubation with all treatments. The Ca-P content was increased rapidly up to 15 days, and the Ca-P has slightly decreased up to 30 days with organic matter plus saline water (T_3) treatment. The Ca-P content was decreased up to 15 days with the saline water (T_2) treatment. Then Ca-P was increased up to 30 days with saline water treatment. The highest value (220.63 µg g^{-1}) was obtained with organic matter plus saline water (T_3) treatment in these soils at the end of 15 days of incubation. The lowest Ca-P content (102.00 µg g^{-1}) was observed in the calcareous soil at the end of 30 days with organic matter (T_1) treatment. The Ca-P content was insignificantly changed with all the treatments from 0 to 30 days.

The calcium-bound phosphorus increased from 0 days to 30 days for all soil series, except T_1. This may be due to an increase of soil pH. Raju and Rao [25] reported that in acid soils calcium bound phosphorus is comparatively less than that of iron and aluminium bound phosphorus. Since iron and aluminium ions are dominant in acid soils, the activity of calcium is low and hence, the amount of calcium bound phosphorus is comparatively low. The change of calcium bound phosphorus from 15 days to 30 days of Barisal series for the treatment T_3, may be due to the presence of a high amount of calcium in the exchange site.

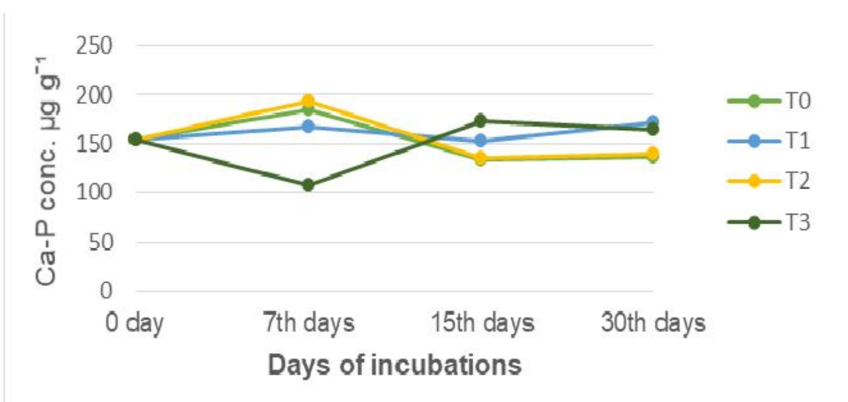

Fig. 5. Change in Ca-P content with time (Barisal soil series)

3.4 Residual Phosphate (RE-P)

For Barisal soil series, (Fig. 7), the residual phosphate (RE-P) was decreased up to 7 days with organic matter (T_1), and saline water (T_2) treatment but the RS-P was increased up to 7 days with organic matter plus saline water (T_3). The residual phosphorus increased for all treatments from 15 days to 30 days. The highest value (300.00 µg g^{-1}) was obtained with saline water (T_2) treatment in Barisal soils series at the end of 30 days of incubation. The lowest RE-P content (65.00 µg g^{-1}) was observed in this soil at the end of 7 days with organic matter (T_1) treatment. The RE-P was similarly changed from 0 to 30 days with all the treatments except organic matter treatment. The change of residual phosphorus with treatments and time was statistically significant (*P*> 0.0001).

For Dumuria soil series, (Fig. 8), the residual phosphorus (RE-P) decreased for all treatments from 0 days to 7 days except organic matter plus saline water treatment. The amount of RE-P then continues to decrease from 7 days to 15 days for all treatments. This increased of RE-P may be due to the increased of other forms of inorganic phosphorus up to 30 days. The residual phosphorus increased for all treatments from 15 days to 30 days. The highest value (295.00 µg g^{-1}) was obtained with T_2 treatment in these soils at the end of 30 days of incubation. The lowest RE-P content (72.00 µg g^{-1}) was obtained in the Dumuria soil at the end of 15 days with saline water treatment. The change of residual phosphorus with treatments and time was statistically significant ($P < 0.001$).

Hamad et al. [26] reported that the amount of Residual Phosphorus in soil depends on the other forms of P. The increased or decreased of residual phosphorus was the result of increased or decreased of other forms of P. Son et al. [27] reported that the residual phosphorus of soil was decreased up to 15 days and after 15 days, it was rapidly increased in amount.

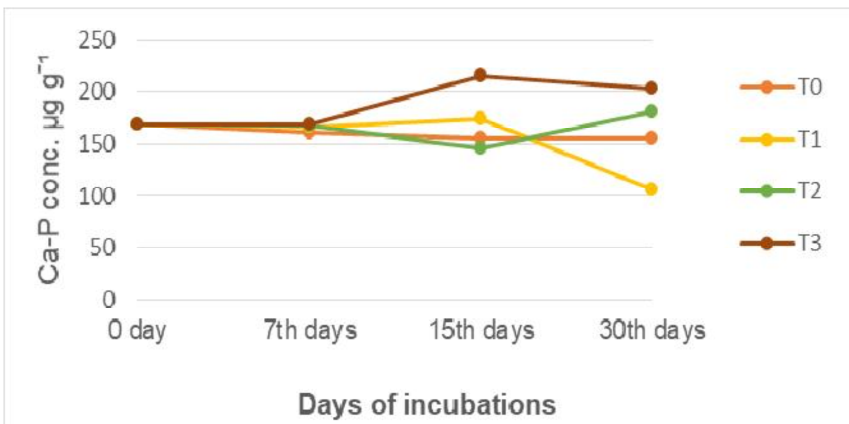

Fig. 6. Change in Ca-P content with time (Dumuria soil series)

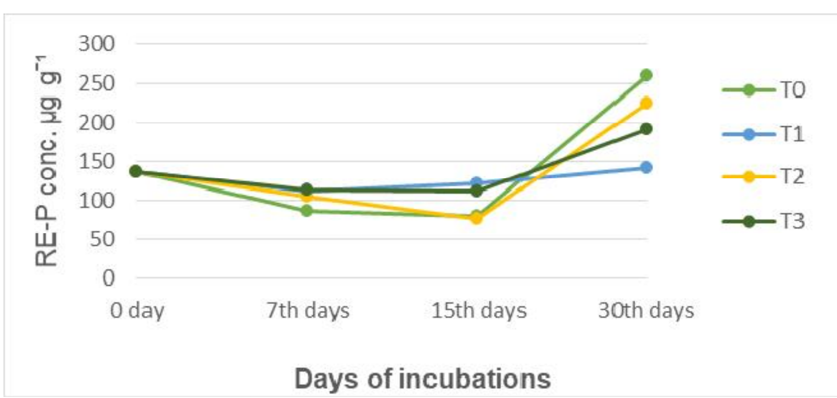

Fig. 7. Change in RS-P content with time (Barisal soil series)

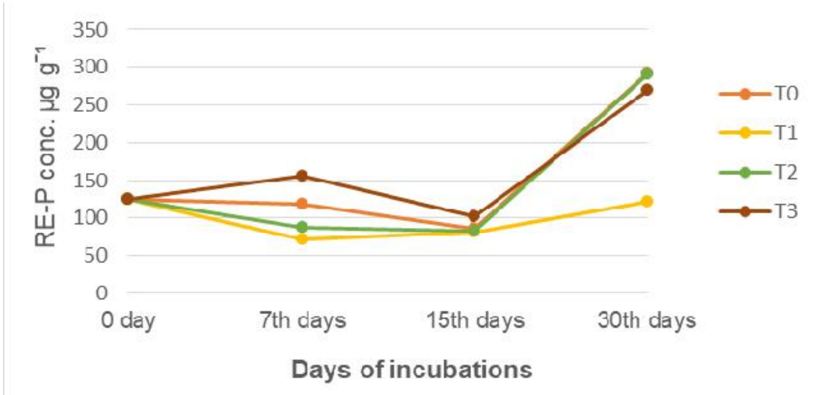

Fig. 8. Change in RS-P content with time (Dumuria soil series)

4. CONCLUSION

Laboratory incubation experiment was conducted up to 30 days with two soil series namely, Barisal and Dumuria to study the influence of soil salinity and organic matter on inorganic Phosphorus transformation with times. The salinity and organic matter treatments were 4 dS m^{-1} and decomposed cow dung 5 t ha^{-1} with three replications. Soil water was maintained at field capacity level. The transformation of inorganic P occurred rapidly due to the influence of salinity and decomposed organic matter treatment. In the course of time, the scenario of those transformations was shifted and showed a different trend from that of the early stages of measurements. The amount of any one portion of the inorganic P transformation depends on the other forms of inorganic P. The increased or decreased concentration of inorganic P resulted from the amount of other portions. Soil salinity as well as decomposed organic matter increases the availability of inorganic P to plants through adsorption procedure and making the solubility of P fixing minerals. The present study examined the soil salinity and decomposed organic matter which increases the availability of P. Further research is needed to study the impact of salinity and organic matter on the transformation of soil P.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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