Evaluation of Residual Effect of Long-term Applied Different Phosphate Sources for Coconut (*Cocos nucifera* L.)

T.N. RAPIEL[1], N.A. TENNAKOON[2], A. NUGAWELA[1] and M.N.D. FERNANDOPULLE[1]

[1]*Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP)*

[2]*Soils and Plant Nutrient Division, Coconut Research Institute of Sri Lanka, Lunuwila*

ABSTRACT

Phosphorus is one of the essential major elements in the coconut. The availability of soil phosphorus to plants depends partly on the concentration of phosphorus in the soil solution. The amount of Phosphorus fertilizer that is to be applied can be cost effectively determined based on the level of residual Phosphorus in that soil. Therefore present study was conducted to determine the residual effect of long-term applied different phosphate sources such as Triple Super Phosphate, Imported Rock Phosphate, and Eppawela Rock Phosphate for coconut in low country intermediate zone (IL_{1a}). Eppawela Rock Phosphate treated soils recorded the highest performance in sub soil and this was confirmed by the leaf P concentration (0.13-0.15%) in the 14th leaf of coconut at the site. Further leaf P value was higher than the critical leaf P concentration (0.12%). Therefore, it can be recommended that the application of phosphorus is not necessary to Eppawela Rock Phosphate treated coconut soils one year after withdrawing of phosphorus fertilizer in low country intermediate zone (IL_{1a}). However, further continuation of this study is needed for firm recommendation.

KEYWORDS: Available phosphorus, Residual effect, Total phosphorus

INTRODUCTION

Coconut (*Cocos nucifera* L.) belongs to the monocot family Arecaceae (Palmaceae) and the subfamily cocoideae. The annual coconut production in 2011 was 2808 million nuts and earned Rs.47,305 million contributing 8.4% to the Gross National Production (GNP), (Anon, 2011) and 1.4% to the Gross Domestic Production (GDP) in total production sector of tea, rubber and coconut (Anon, 2011).

Coconut is an important crop, mainly grown in low country and mid country, from the coastal area up to about 500 m above mean sea level in wet or intermediate climate conditions. Majority of coconut plantations are located in sandy, sandy loam and lateritic soils. These soils inherently low in fertility and some are being light textured are subjected to heavy leaching during rainy season. Coconut being a perennial crop, demands a continuous supply of a large amount of nutrients. It is estimated that coconut grown in one hectare, yielding 7900 nuts per year removes about 75 kg N, 8 kg P, 142 kg K and 28 kg Mg per year as nuts, leaves, coconut shedding etc. (Somasiri *et al.*, 2003) which necessitate a regular and well-planned manuring program to maintain both the soil fertility and the coconut production.

Phosphorus is considered to be a relatively immobile element compared with most of the other plant nutrients in the soils. Phosphorus fertilizer was reported not to have moved below the surface soil even after several years of continued application (Brown, 1935; Stanberry *et al.*, 1955; Pratt *et al.*, 1956; Humphreys and Pritchett, 1971). Plants take up phosphorus as orthophosphate ions from the soil solution. The total amount of dissolved phosphorus in the root penetrated soil profile is 0.1 – 1.0 kg/ha. As normal crops must take up 15-30 kg/ha of P during a few months it is obvious that the P content of the soil solution must be renewed from the solid phases frequently during the growth period (Anon, 1987).

The availability of soil phosphorus to plants depends partly on the concentration of phosphorus in the soil solution and partly on the rate at which more phosphorus comes into solution when already dissolved P is taken up by a plant. The extent to which added fertilizer phosphorus increases the supply of phosphorus to plants growing on a soil depends on the type of fertilizer and soil characteristics. Water soluble phosphate, as in superphosphate or mono-ammonium phosphate, added to alkaline soils is absorbed and gradually precipitated as calcium phosphate. In strongly acid soils most of the phosphorus is present as aluminum and iron phosphates. In neutral or calcareous soils the stable phase is usually some form of apatite mineral or high order calcium phosphate (Anon, 1987).

Normally organic matter increases the solubility of phosphate in soils. The organic matter itself contains phosphorus. Roughly

50% of the total phosphorus in a soil with variations from 20 to 80% is bound up in organic compounds. The organic phosphorus is continuously released as orthophosphate ions when the organic matter is broken down by microorganisms.

The basic iron and aluminum phosphates have a minimum solubility pH 3 to 4. At higher pH values some of the phosphorus is released and the fixing capacity reduced. Even at pH 6.5, however, much of the phosphorus is still probably chemically combined with iron and aluminum. As the pH approaches 6, precipitation as calcium compounds begins; at pH 6.5 the formation of insoluble calcium salts is a factor in rendering the phosphorus unavailable. (Buckman and Brady, 1969).

As the pH increased, the amount of residual phosphate extracted by acetic acid increased. These results confirm those of Dean (1938), and both authors concluded, reasoning by analogy from the solubility of the known compounds, that the retention of phosphate in calcareous soils is due largely to precipitation by calcium. Williams (1950b) also studied the residual phosphate in soils varying in pH from 6.5 to 8.9. The proportion of the residual phosphate extractable by acid increased as the pH increased.

The amount of Phosphorus fertilizer that is to be applied can be cost effectively determined based on the level of residual Phosphorus in that soil. Therefore this research was focused to study the residual effect of phosphorus in the soil after long term application of different phosphorus fertilizers for coconut from 1991.

MATERIALS AND METHODS

Experimental Site and Treatments

Research was conducted in Soils and Plant Nutrition Division at Coconut Research Institute (CRI), Lunuwila. Soil and leaf samples were taken from the ongoing experiment on studies on long-term effect of different phosphate application to coconut at Rathmalagara estate. The experimental site falls in the low country intermediate zone (IL_{1a}). The soil of this site was Andigama soil series (Red Yellow Podzolic) belonging to land suitability class S4. This had been commenced in 1991. Treatments had not being applied for this experiment since 2010. Samplings had been done after 2010.

Treatments had been given as follows.

T1 –TSP 400 g per palm/yr
T2 – IRP 600 g per palm/yr
T3 – ERP 900 g per palm/yr
T4 – Control (No phosphorus source)

Sampling and Sample Preparation

Soil and Leaf Sampling

Soil samples were collected from the manure circle (MC) of the three randomly selected coconut palms in each plot to make composite sample. The soil samples were taken at two depths; 0-20 cm and 20-40 cm separately. The sample was dried at room temperature for three days. The dried sample was sieved using 2 mm sieve and stored for chemical analysis.

Composite leaf samples were taken from the above randomly selected coconut palms. Leaf samples were taken from the leaflets arising from a 10 cm long mid portion of the 14^{th} frond (counting from the 1^{st} fully opened frond) from one palm. Leaf samples were dried at oven temperature of 85 °C.

Soil Chemical Analysis

Soil Parameters

The soil electrical conductivity and pH were measured (1:5 w/w water) electrometrically (Black, 1965).

Available Phosphorus

The available phosphorus in soil samples were determined by extraction with 2.5% acetic acid. The phosphorus concentrations were analyzed colorimetrically using the spectrophotometer at 660 nm wavelength by the molybdenum blue colour method (Lab manual CRI, 2000).

Total Phosphorus

Powdered soil samples were digested with $HClO_4$ acid. The phosphorus concentrations were analyzed colorimetrically using the spectrophotometer at 660 nm wave length by the molybdenum blue colour method (Lab manual CRI, 2000).

Leaf Chemical Analysis

Leaf Phosphorus

Powdered leaf samples were digested with 4:1 mixture of HNO_3 and $HClO_4$ acid and the content of leaf phosphorus were determined using Auto analyzer (Lab manual CRI, 2000).

Leaf Nitrogen

Powdered leaf samples were digested with 0.4% Selenium Sulphuric solution analysis using Auto analyzer (Lab manual CRI, 2000).

Statistical Analysis

The data were analyzed using SAS/STAT Package (Anon, 1999b). Randomized

Complete Block Design (RCBD) was used as the analytical design.

RESULTS AND DISCUSSION

Soil Parameters

The favorable pH range for coconut is 5 to 7 (Biswas and Mukherjee, 1987). The pH ranged from 6.59 to 7.00 and 5.50 to 6.28 in top and sub soils respectively among the treatments (Table 1). IRP treated soil recorded the highest pH value (7.00) in top soil but no significant different with TSP, ERP and control treated soils. The control treatment recorded the lowest value (6.59). At sub soil ERP treated soil showed high values of pH 6.28 but it was not significantly different with IRP and no phosphorus sources (control) treated soils. It was significantly different with TSP treated soil. The TSP treatment recorded the lowest value (5.50). This low pH value in sub soil could be due to increased H^+ ion concentration by high dissolving of leached TSP after long-term application. However, the pH of the sub soil was lower than the top soil.

There were no significant differences in EC among the treatments. However, it ranged from 27.27 µs/cm to 38.70 µs/cm and 25.43 µs/cm to 39.83 µs/cm in top and sub soils respectively among the treatments (Table 1). ERP treated soil showed high values of EC 38.70 µs/cm and 39.83 µs/cm in top soil and sub soils respectively.

Table 1. pH and EC of top soil and sub soil in different treatments

Treatments	pH		EC (µs/cm)	
	0-20(cm)	20-40(cm)	0-20(cm)	20-40(cm)
T1	6.68	5.50b	31.97	25.43
T2	7.00	6.05a	38.27	30.33
T3	6.69	6.28a	38.70	39.83
T4	6.59	5.93a	27.27	26.53
LSD<0.05	NS	0.4172*	NS	NS

*Means with different letters within the same column represent significant differences at $P < 0.05$ level, *Significant at $p<0.05$, NS – not significant.*

Determination of Available Phosphorus

Available phosphorus was ranging from 52.85 mg/kg to 344.34 mg/kg in top soil among the treatments (Table 2). IRP treated soil recorded the highest value (344.34 mg/kg) in top soil though not significantly different with TSP, ERP and no phosphorus treated soils.

At sub soil ERP treated soil showed high values of available phosphorus 165.67 mg/kg and it was significantly different with TSP, IRP and no phosphorus treated soils. The no phosphorus treated soil recorded the lowest value (17.42 mg/kg).

In control treatment where no phosphate fertilizer had been applied for about 20 years, phosphorus concentration of the top soil was found to be higher than the sub soil. This high concentration of available phosphorus in top soil could be due to the residual effect of phosphorus fertilization during 20 years. The available nutrient could be easily fixed into the clay materials and also to the organic fraction of the soil and keeping it in the manure circle available for coconut for long period (Brady, 1990). Large initial application of phosphorus to high phosphorus fixing soils had a marked residual effect on the yield of corn (*Zea mays*) 7 to 9 years after application (Kamprath, 1967).

Determination of Total Phosphorus

Total phosphorus was ranging from 167.64 mg/kg to 375.47 mg/kg in top soil among the treatment (Table 2). These values are much lower than the typical value of 395 mg/kg reported for the uncultivated mineral soils of U.S.A. (Robinson *et al.*, 1917).

IRP treated soil recorded the highest value (375.47 mg/kg) in top soil but was not significantly different with TSP, ERP and no phosphorus treated soils.

At sub soil ERP treated soil showed high values of total phosphorus 367.15 mg/kg and it was significantly different with TSP, IRP and no phosphorus treated soils. The no phosphorus treated soil recorded the lowest value (116.38 mg/kg). Addition of insoluble form of phosphate fertilizer enhances the residual effect (Anon, 1999a). The evidence indicated that the residual value of applied phosphates is the greatest in neutral soils, somewhat less in alkaline calcareous soils and the least in acid soils (Pierre and Normon, 1953).

Analysis of Leaf Phosphorus

No significant differences were observed in leaf phosphorus among the treatments (Table 3). The leaf P concentrations ranged from 0.13 to 0.15% and having values higher than the critical 14th leaf P concentration, 0.120% in coconut (Fermond *et al.*, 1966; Kanapathy, 1971; Magat, 1979). This is in accordance with the soil data, which also showed that the soils were sufficient in phosphorus. Loganathan *et al.* (1982) reported that the leaf P concentration in the 14th leaf of coconuts in the 35 selected unfertilized sites representing all coconut growing soils ranged from 0.074 to 0.116%.

Table 2. Available phosphorus and Total phosphorus of top soil and sub soil in different treatments (mg kg^{-1})

Treatments	Available phosphorus		Total phosphorus	
	0-20(cm)	20-40(cm)	0-20(cm)	20-40(cm)
T1	109.81	36.03b	288.18	178.73b
T2	344.34	91.59ab	375.47	163.49b
T3	292.70	165.67a	317.27	367.15a
T4	52.85	17.42b	167.64	116.38b
LSD<0.05	NS	114.87*	NS	132.15*

*Means with different letters within the same column represent significant differences at P < 0.05 level, *Significant at p<0.05, NS – not significant.*

Analysis of Leaf Nitrogen

There were no significant differences in leaf nitrogen among the treatments. The leaf nitrogen concentration ranged from 2.03 to 2.17% (Table 3). However it was above the critical level (1.9%-2.1%).

Table 3. Treatment effect on leaf nutrients

Treatments	N%	P%
T1	2.17	0.15
T2	2.03	0.13
T3	2.07	0.14
T4	2.04	0.13
LSD<0.05	NS	NS

**Significant at p<0.05, NS – not significant*

CONCLUSIONS

The results of the study revealed that residual effect of ERP led to maximum available phosphorus in sub soil. The higher levels of leaf P in the palms than the critical leaf P, where after long term applied phosphate fertilizer, confirmed sufficient phosphorus in the soil.

Therefore, the application of phosphorus is not necessary to ERP treated soils one year after withdrawn of phosphorus fertilization. Since the study is based only on one year after withdrawing of phosphorus fertilization, the observations need some further verification. Therefore, further continuation is needed to arrive at firm recommendation.

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