# Assessment of the Available Phosphorus in Two Soil Series under Different Fertilizer Used for Coconut (*Cocos nucifera*) in Gampaha District of Sri Lanka

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## ABSTRACT

**Currently, coconut cultivation in Gampaha District is largely carried out either with annual fertilizer application or without fertilizer at all. Therefore, this study aims to investigate the available phosphorus in two major coconut growing soils of Gampaha District in Sri Lanka in relation to organic manure and inorganic fertilizer applied sites with the objective of mapping available phosphorus in Gampaha District. The experimental sites were selected to represent two major coconut growing soils-Boralu and Pallama series in Gampaha District and to include three types of fertilizer treatments; i.e., treated with organic manure, inorganic fertilizer and no fertilizer for the past five year period. The available phosphorus of 120 soil samples and leaf samples was analyzed. The results showed that Boralu and Pallama soil contained 'medium' amount (16mg/kg) of available phosphorus irrespective of fertilizer treatments and this was confirmed by the leaf-P concentrations (0.135-0.196%) in the 14$^{th}$ leaf of coconut at the soil sites were all higher than the critical leaf-P concentration (0.120%).**

KEY WORDS: **Available Phosphorus, Boralu Soil Series, Coconut, Fertilizer, Pallama Soil Series.**

## INTRODUCTION

Coconut (*Cocos nucifera*) in Sri Lanka is of great importance to the economy of the country as it contributes to the Gross Domestic Production (GDP) by 2.0% giving an annual foreign exchange earning of 8926 million rupees (Anon[a], 2003).

Out of the total extent under coconut in Sri Lanka, the "Coconut Triangle"- North Western Province (Kurunegala & Puttalam Districts) and a part of Western Province (Gampaha District), represent 61% of the country's coconut growing lands excluding coconut in the mixed stands and home gardens (Anon[b], 2003). Within the coconut triangle, Gampaha District bears 8% of pure coconut stand out of the total extent (Anon[b], 2003).

Out of the major nutrients for coconut, phosphorus is an important essential major nutrient for both young (non-bearing) and adult (bearing) coconut. Application of phosphorus has been shown to increase the number of leaves, girth at collar and root density of coconut seedlings and in young palms, increases leaf production, lower the age of flowering and reduces the incidence of the fungus *Helminthosporium incurvatum* attack on leaves (Loganathan *et al.*, 1984).

Of the coconut growing countries in the world, Sri Lanka alone appears to have shown consistently significant effects on nut and copra yield to the application of phosphorus fertilizer (Loganathan *et al.*, 1984). Experiments carried out on mature palms at Madampe, Veyangoda, Ahangama, Bandirippuwa, Pothukulama and Bingiriya in Sri Lanka showed spectacular yield responses to application of phosphorus (Loganathan *et al.*, 1984).

The soil supporting coconut in Sri Lanka was generally deficient in total as well as the active and available forms of phosphorus. Although soils of the Ultisols had marginal to moderate amounts of total phosphorus, the active and available fractions were extremely low (Loganathan *et al.*, 1984). The results of the leaf analytical data from the joint FAO/CRI/CCB study in increasing yield in small holdings by the use of fertilizer revealed that about 85-90% lands have excess or adequate levels of phosphorus and according to the present nutritional order of priority for adult coconut in Sri Lanka; phosphorus takes the 4$^{th}$ place (AR/CRI, 1989).Therefore, the present study aims at the determination of available phosphorus in major two coconut growing soils of Gampaha District namely Boralu and Pallama series in relation to organic manure and inorganic fertilizer applied annually for more than 10 years with the objective of preparing a nutrient map of available phosphorus in that area. Hence this information on the available phosphorus of these soils is helpful to provide a rough estimate of the phosphorus needed to coconut as well as the associated crops cultivated or to be cultivated in the space between the palms.

So this paper describes the available phosphorus extracted by Bray and Kurtz No.1 method in major two soil series namely Pallama and Boralu in great soil group of red yellow podzolic in Gampaha district, the variation of available phosphorus with the different fertilizer management practices in these soils, P-nutritional status of the palms in some of these sites and the relationship between leaf Phosphorus and available soil phosphorus.

## MATERIALS AND METHODS

The study was conducted in the Soils and Plant Nutrition Division of the Coconut Research Institute, Lunuwila, Sri Lanka during the period of December 2004 to June 2005.

*Collection of Soil Samples*

Soil samples from two major soil series of great soil group-Red Yellow Podzolic in the agro-ecological region of WL3 ( Gampaha District ) viz. Boralu series and Pallama series covering an extent of 32,400ha were sampled at the rate of one sampling location per every 270ha. Soil sampling sites are shown in Figure 1.

Altogether 120 soil samples were collected from locations representing 30 sites of all coconut growing areas of Boralu and Pallama soil series of Gampaha District. They were comprised of 40 soil samples from coconut holdings where no fertilizer had been added at least during previous five years, 40 soil samples from annually fertilized coconut stands with organic manure (Cattle manure + APM or Poultry manure+ APM or Green Manure + APM) and 40 soil samples from annually fertilized coconut lands with inorganic fertilizer (Adult Palm Mixture-APM).

Soil samples were collected from four palms in each site and in each palm from four points of the manure circle at two depths (0-25cm and 25-50cm) separately. These soil samples were composited to represent each soil depth. Another soil sample was collected from the center of square formed by four coconut palms at two depths (0-25cm and 25-50cm) at four points in each site and bulked according to the depth to form the sample representing the site. Soil samples were collected from both soil series viz. Boralu and Pallama.

The collected soil samples were air-dried (25-30°C for 3-5days) in the laboratory, ground with a wooden pestle, passed through a 2mm sieve and stored for chemical analysis ( pH, Electrical Conductivity and available phosphorus).

*Collection of Leaf Samples*

In order to determine the P-nutritional status of the coconut palms in the sites where fertilizer were applied, leaflets from the middle portions (10cm length) of the 14th frond (selected by counting downward from the first fully opened frond as the 1st frond) of four palms in each of 10 selected sites were collected and the samples collected from four palms at each site were bulked to represent the site.

The collected leaf samples were washed in running tap water, then with distilled water three times and oven dried at 85°C for a maximum of 72 hours. Then the samples were powdered using a hammer mill with stainless steel grinder and stored in polythene bags until the chemical analysis of leaf was done.

***2.1 Analysis of Soil Samples***

**2.1.1 Determination of electrical conductivity (EC)**

The EC of the soil samples was determined by making a 1:5 suspension with 10g of sieved (2mm), air dried soil and 50ml of distilled water. The soil suspension was stirred and left to equilibrate for 30 minutes. Then the EC of the soil samples was measured electrometrically without disturbing the soil samples using an Orion Research Model 145A plus EC meter (Tropical soil and leaf analytical methods, 1982).

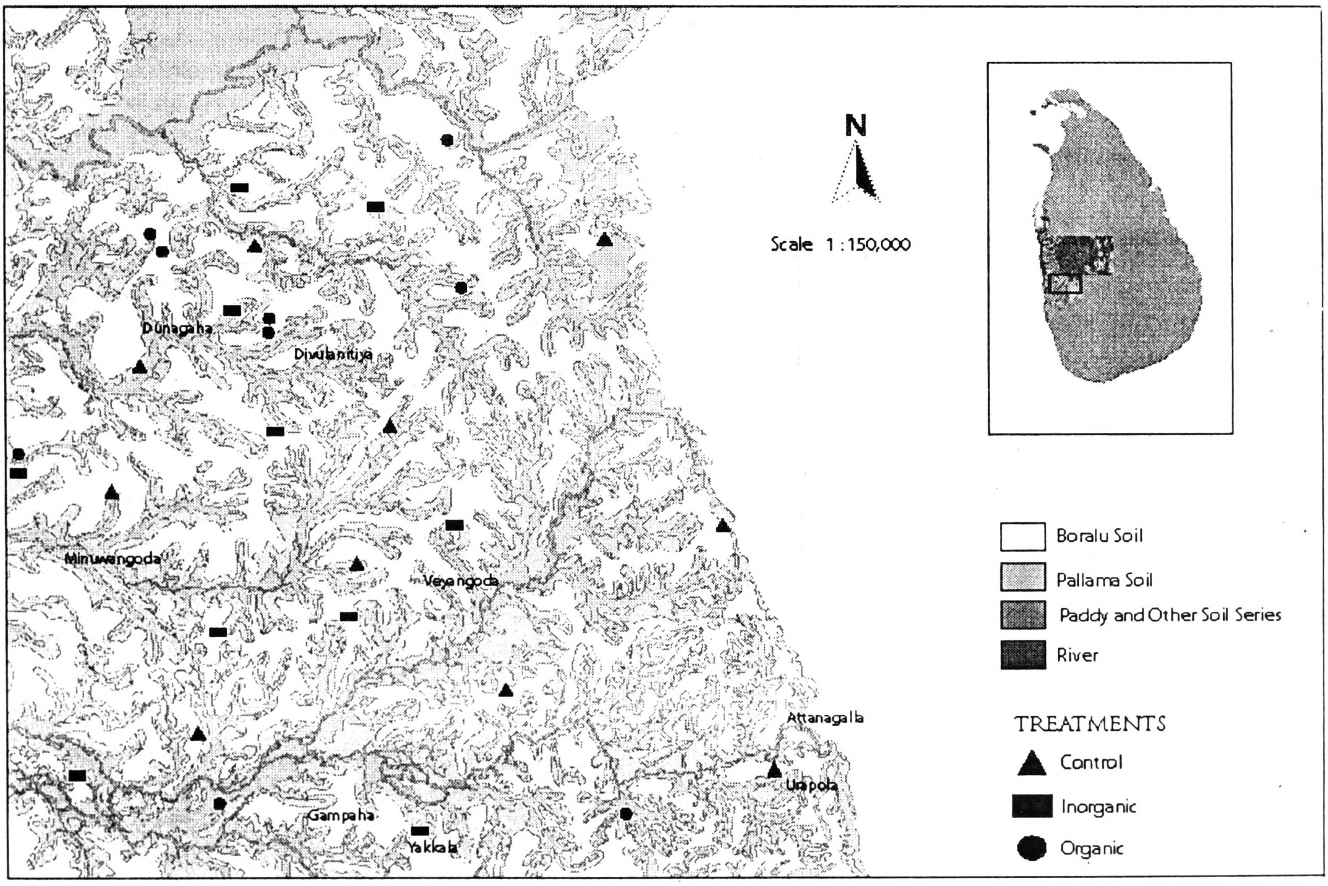


Figure01 : SAMPLING LOCATIONS IN GAMPAHA AREA

**2.1.2 Determination of pH (1:5w/w water)**

The soil samples after measuring the EC were stirred and their pH values were measured electrometrically using an Orion Research Model 410A plus pH meter after calibrating the instrument at pH 4 and pH 7 (Black *et al.*, 1965).

**2.1.3 Determination of available phosphorus**

The soil samples were further ground with a motor driven agate mortar and passed through a 0.15mm (100 meshes) sieve. The available phosphorus in soil samples was determined by extraction with acid fluoride: Bray and Kurtz No.1 method (Bray and Kurtz, 1945). The phosphorus concentrations were then analyzed colorimetrically using the spectrophotometer (CE 2030) at 660nm wave length by the molybdenum blue colour method (Murphy and Rilye, 1962).

***2.2 Analysis of Leaf Samples***

Leaf samples were digested with 4:1 mixture of $HNO_3$ and $HClO_4$ acid and the content of leaf phosphorus was determined using Auto Analyzer-Technicon II (Tropical soil and leaf analytical methods, 1982).

***2.3.Data Analysis***

The data were analyzed using SAS/STAT Package. The analytical design used was Completely Randomized Design with factorials.

## RESULTS AND DISCUSSION

***3.1 Analysis of Soil Samples***

**3.1.1Determination of electrical conductivity (EC)**

The electrical conductivity values of the soil varied within a wide range from 20.2 to 155.6µs/cm with a general mean value of 62.66µs/cm for all soil samples analyzed irrespective of fertilizer applications (Table 1). The EC of top soil showed significant difference ($P<0.001$) from the sub soil leading to higher amount of ions in the top soil with a mean value of 78.18 ± 39.19µs/cm than the sub soil having a mean value of 47.14 ± 24.14 µs/cm. Top soil is generally fertile due to fertilizer application and availability of soil organic matter as a result of application of mulch. Therefore ion concentration in top soil is high. Also according to the position, manure circle significantly differed ($P<0.05$) from the centre of square due to application of fertilizer having a mean value of 71.82 ± 37.59µs/cm than the centre square of 53.13 ± 31.79µs/cm mean value.

The mean EC values were 71.25, 58.43 and 58.26µs/cm in the unfertilized soil, inorganic fertilizer applied soil and organic manure applied soil respectively though they were not significantly different. In the Boralu and Pallama soil series, mean EC values were 66.04 and 58.54µs/cm respectively, showing no significant difference between them Among all sites analyzed, 19.5% of sites showed >100µs/cm of EC value.

**3.1.2 Determination of pH**

The pH of the soil varied from 4.04 to 6.83 as shown in Table 2. The pH values were significantly different ($P<0.001$) among the different fertilizer treatments. Though the control was significantly differed from the fertilizer applied soil, two types of fertilizer treatments- inorganic fertilizer and organic manure applied soils were not significantly different.

Between Boralu and Pallama soil series or the position of the soil or the depth of the soil, there was no significant difference of the soil pH. While the mean pH values in Boralu and Pallama soil series were 4.97 and 4.86 and in centre of square and manure circle were 4.84 and 5.00 respectively. Also the mean pH values of top soil and sub soil were 4.91 and 4.93 respectively.

**Table 1. Electrical conductivity values (mean ± sd) of top soil and sub soil in the manure circle (MC) and centre of square (CS) of Boralu and Pallama soil series receiving different fertilizer treatments.**

| Fertilizer Practice | Position | Electrical Conductivity (µs/cm) | | | |
|---|---|---|---|---|---|
| | | Boralu soil series | | Pallama soil series | |
| | | Top soil[a] | Sub soil[b] | Top soil[a] | Sub soil[b] |
| Organic | MC | 78.4 ± 42.4 | 58.8 ± 15.8 | 45.3 ± 22.9 | 46.1 ± 4.4 |
| | | (38.9 - 136) | (42.0 - 80.5) | (29.5 - 61.5) | (43.0 - 49.2) |
| | CS | 62.6 ± 20.9 | 40.2 ± 10.7 | 93.9 ± 39.0 | 27.7 ± 9.4 |
| | | (32.8 - 81.5) | (24.2 - 53.5) | (58.6 - 136) | (20.4 - 38.3) |
| Inorganic | MC | 80.5 ± 18.9 | 58.4 ± 31.4 | 90.4 ± 53.2 | 47.6 ± 10.3 |
| | | (52.6 - 101) | (20.7 - 104) | (31.9 - 156) | (34.9 - 60.5) |
| | CS | 55.5 ± 16.8 | 34.7 ± 4.3 | 70.2 ± 45.0 | 30.2 ± 12.9 |
| | | (43.1 - 76.3) | (30.3 - 39.5) | (29.7 - 35) | (20.2 - 49.5) |
| Control | MC | 126.9 ± 43.6 | 80.6 ± 40.6 | 66.4 ± 32.7 | 42.1 ± 11.6 |
| | | (49.8 - 151) | (52.8 - 149) | (41.6 - 112) | (31.6 - 58.8) |
| | CS | 69.5 ± 45.8 | 38.3 ± 15.6 | 9.2 ± 41.4 | 49.5 ± 35.6 |
| | | (34.6 - 137) | (27.6 - 60.7) | (28.0 - 122) | (20.9 - 101) |

*Values in parentheses denote the range.* *[a]Top soil = 0-25 cm* *[b]Sub soil = 25-50 cm*

**Table 2. pH values (mean ± sd) of top soil and sub soil in the manure circle (MC) and centre of square (CS) of Boralu and Pallama soil series receiving different fertilizer treatments.**

| Fertilizer Practice | Position | pH | | | |
|---|---|---|---|---|---|
| | | Boralu soil series | | Pallama soil series | |
| | | Top soil[a] | Sub soil[b] | Top soil[a] | Sub soil[b] |
| Organic | MC | 5.09 ± 0.45<br>(4.35 - 5.46) | 4.98 ± 0.44<br>(4.51 - 5.63) | 4.94 ± 0.52<br>(4.58 - 5.31) | 4.64 ± 0.07<br>(4.59 - 4.69) |
| | CS | 5.01 ± 0.25<br>(4.73 - 5.40) | 5.04 ± 0.56<br>(4.58 - 5.98) | 4.82 ± 0.11<br>(4.74 - 4.94) | 4.87 ± 0.09<br>(4.77- 4.96) |
| Inorganic | MC | 5.48 ± 1.01<br>(4.42 - 6.83) | 5.34 ± 1.01<br>(4.16 - 6.75) | 5.39 ± 0.47<br>(4.78 - 6.07) | 5.11 ± 0.33<br>(4.73 - 5.63) |
| | CS | 5.20 ± 0.73<br>(4.35 - 5.99) | 5.13 ± 0.47<br>(4.59 - 5.68) | 4.64 ± 0.49<br>(4.04 - 5.31) | 4.88 ± 0.32<br>(4.47 - 5.33) |
| Control | MC | 4.47 ± 0.31<br>(4.11 - 4.95) | 4.66 ± 0.25<br>(4.35 - 4.99) | 4.76 ± 0.25<br>(4.44 - 5.08) | 4.84 ± 0.17<br>(4.66 - 5.05) |
| | CS | 4.50 ± 0.16<br>(4.28 - 4.70) | 4.68 ± 0.31<br>(4.26 - 5.01) | 4.55 ± 0.31<br>(4.07 - 4.89) | 4.74 ± 0.17<br>(4.54 - 4.96) |

***$LSD_{0.05}$ for fertilizer practice = 0.217***

***Values in parentheses denote the range.*** ***[a]Top soil = 0-25 cm [b]Sub soil = 25-50 cm***

The pH values obtained from this study showed that all sampling sites were in favourable pH range introduced by Pethiyagoda (1980) for coconut cultivation.

**3.1.3 Determination of available phosphorus**

The available phosphorus by the Bray and Kurtz No.1 method did not show any relationship to soil series. The available phosphorus values were in very wide ranges, as shown in Table 3, which indicate that the availability of phosphorus in two major coconut growing soils are highly variable.

Based on the tropical level of 10mg/kg for available phosphorus in soil (Brady, 1990), available phosphorus in manure circles of 85% sites from the control were in sufficient level while 100% of the sites where organic manure applied and 90% of the sites where inorganic fertilizer applied were sufficient in available phosphorus.

But 35% sites of the center of square soil in the control were sufficient in available phosphorus and 85% and 90% sites from the inorganic fertilizer and organic manure applied soil were sufficient in available phosphorus respectively. Available phosphorus in sampling sites is indicated in Figure 2.

In control treatment where no fertilizer had been applied for about five years, phosphorus concentration of the manure circle was found to be significantly higher than the center of square. This high concentration of available phosphorus in manure circle could be due to the residual effects of phosphorus fertilization over five 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). Also available phosphorus of sub soil (22.7mg/kg) was significantly different from the top soil (34.7mg/kg) in the same site ($P<0.01$).The high level of organic matter and its clay content in top soil led to higher available phosphorus in top soil. The surface retention of phosphate was also observed by some other workers in sandy soil, red yellow podzolic soil and some kind of coconut soils ( Chang and Cbu, 1961; Bromfield,1965; Loganathan *et al.*, 1983; Amalu and Obigbesan, 1990).

There was a significant difference ($P<0.01$) of phosphorus availability in the soil among different fertilizer treatments irrespective of the soil series as well. The mean concentration of available phosphorus in the control, inorganic fertilizer applied and organic manure applied soils were 20.63, 33.35 and 31.46mg/kg respectively. Though the control was significantly different from two treatments, the two treatments -inorganic fertilizer and organic manure applied soils did not show any significant difference.

The available phosphorus in the center of square of the control was ranged from 4.8 to 31.8mg/kg and mean was 16mg/kg. Loganathan *et al.*, (1984) indicated that Bray and Kurtz No.1P ranged from 0.2 to 3.6mg/kg with a mean of 1.3mg/kg for all unfertilized soils in Sri Lanka. The 16mg/kg of mean available phosphorus value obtained in this study could be due to the annual application of fertilizer to those lands before five years. The phosphorus source in coconut fertilizer mixture could be either as Imported Rock Phosphate (IRP) or Eppawala Rock Phosphate (ERP) and both those phosphorus fertilizer tend to decompose slowly and release phosphorus to the soil for a longer period. Wahid (1977) reported that laterite soils of coconut-growing regions of India contained Bray and Kurtz No.1P of 8.5mg/kg.

**Table 3. Available phosphorus (mean ± sd) of top soil and sub soil in the manure circle (MC) and centre of square (CS) of Boralu and Pallama soil series receiving different fertilizer treatments.**

| Fertilizer Practice | Position | Phosphorus (mg/kg) Boralu soil series Top soil[a] | Boralu soil series Sub soil[b] | Pallama soil series Top soil[a] | Pallama soil series Sub soil[b] |
|---|---|---|---|---|---|
| Organic | MC | 48.5 ± 20.2 (24.0 - 72.1) | 52.0 ± 31.1 (23.0 - 98.4) | 27.5 ± 3.4 (25.1 - 29.8) | 12.5 ± 1.1 (11.7 - 13.3) |
| | CS | 33.5 ± 17.7 (12.5 - 51.9) | 21.6 ± 6.4 (15 - 29.9) | 22.8 ± 1.7 (20.9 - 24.3) | 24.4 ± 14.4 (9.9 - 38.7) |
| Inorganic | MC | 50.7 ± 33.5 (14.7 - 81.0) | 32.5 ± 31.3 (7.1 - 67.5) | 69.0 ± 33.3 (31.4 - 97.4) | 37.3 ± 23.8 (9.8 - 72.4) |
| | CS | 23.8 ± 5.0 (17.2 - 29.8) | 13.9 ± 5.1 (9.2 - 20.7) | 20.9 ± 9.9 (6.5 - 31.6) | 18.9 ± 3.9 (12 - 21.8) |
| Control | MC | 21.4 ± 18.7 (9.4 - 49.0) | 29.3 ± 13.3 (10.8 - 48.1) | 19.2 ± 6.4 (12.8 - 25.6) | 18.7 ± 12.3 (6.3 - 36.8) |
| | CS | 11.4 ± 4.5 (4.8 - 14.2) | 13.1 ± 10.9 (6.2 - 25.6) | 17.1 ± 13.7 (4.5 - 31.8) | 7.0 ± 1.7 (4.6 - 9.1) |

*$LSD_{0.05}$ for fertilizer practice = 9.473*

*Values in parentheses denote the range.* *[a]Top soil = 0-25 cm* *[b]Sub soil = 25-50 cm*

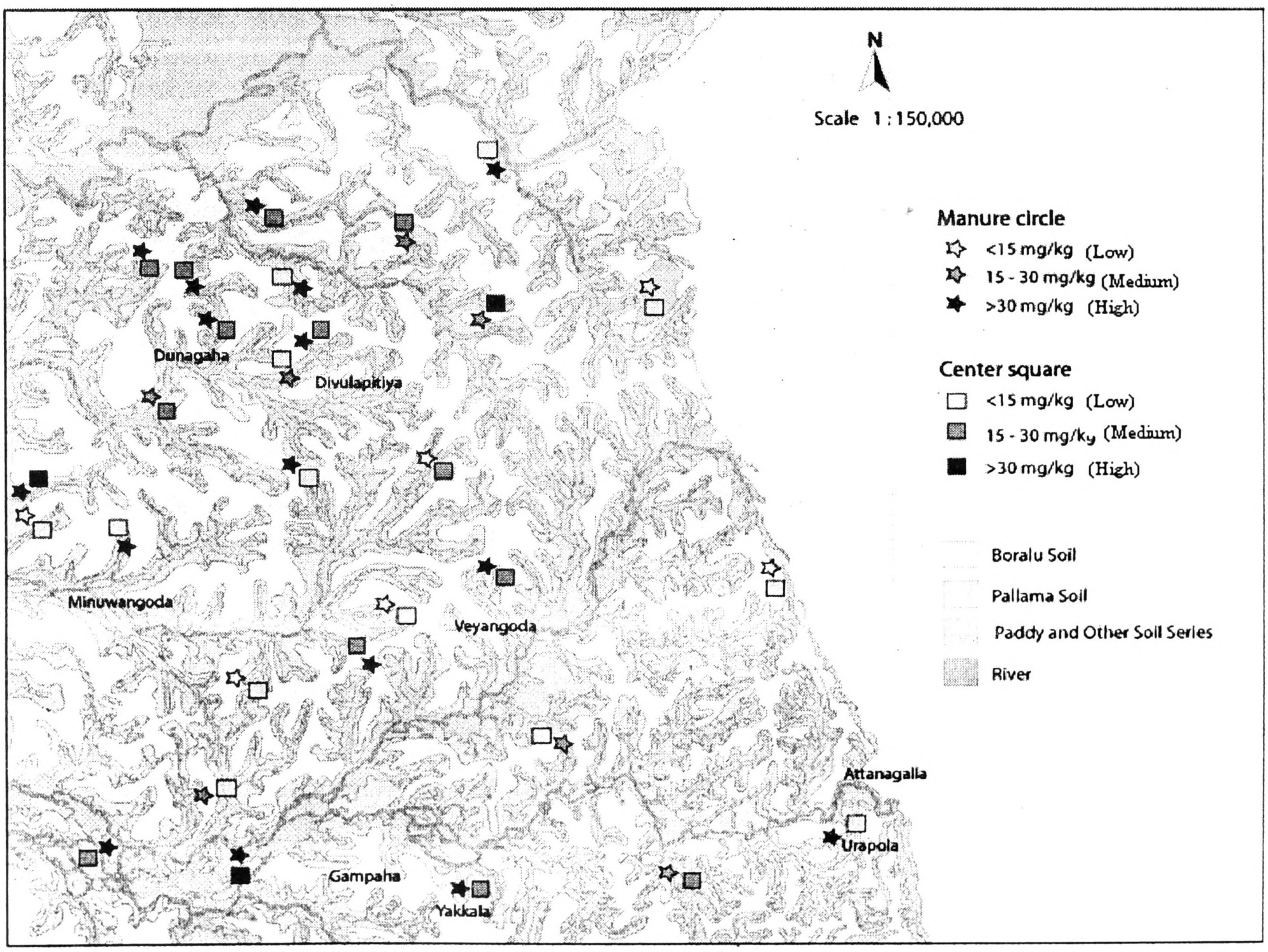


Figure 02 : AVAILABLE PHOSPHORUS OF SAMPLING LOCATIONS IN GAMPAHA AREA

Thomas and Peaslee (1973) reported that most soils containing extractable phosphorus of less than 15mg/kg as determined by Bray and Kurtz No.1P method were 'low' in available phosphorus and values of 16 to 30mg/kg was 'medium' with respective to phosphorus availability. Although the above values were reported for different crops under soil conditions other than those of Sri Lanka, nevertheless they could be served as a guide in evaluating the phosphorus availability in the soils of Sri Lanka. Based on these values, Boralu and Pallama unfertilized soil (Control) of Gampaha District appear to have 'medium' contents of available phosphorus while both inorganic (APM) fertilizer applied and organic manure applied Boralu and Pallama manure circle soil contain 'high' amount (>30mg/kg) of available phosphorus. But centre of square soil of both inorganic fertilizer and organic manure applied, contains 'medium' amount of available phosphorus.

### *3.2 Analysis of Leaf Phosphorus*

Leaf-P concentrations in the 14th leaf of coconut at ten selected fertilizer applied sites were ranged from 0.135 to 0.196% (mean of 0.163%) and 0.142 to 0.187% (mean of 0.162%) in Boralu and Pallama soil series respectively as shown in Table 4 having values higher than the critical 14th leaf-P concentration, 0.120% in coconut (Fremond, Ziller and De Nuce De Lamothe, 1966; Kanapathy, 1971; Magat, 1979; Manciot *et al.*, 1979). This is in accordance with the soil data, which also showed that the soils were sufficient in phosphorus.

**Table 4. Leaf phosphorus concentration (mean ± sd) of 14th fronds of palms receiving fertilizer in Boralu and Pallama soil series.**

| Soil Type | Leaf phosphorus (%) |
|---|---|
| Boralu | 0.163 ± 0.023 |
| | (0.135 - 0.196)* |
| Pallama | 0.162 ± 0.016 |
| | (0.142 - 0.187)* |

***Range with in parentheses.***

Loganathan *et al.*, (1984) reported that leaf-P concentrations in the 14th leaf of coconuts in the 35 selected unfertilized sites ranged from 0.074 to 0.116% in all coconut growing soils.

### *Correlation of Leaf Phosphorus Concentration with Available Phosphorus in Soil.*

Nair (1979) reported that the critical nutrient levels themselves are dependent on a number of environmental and plant characters and they did not reflect the nutrient supplying capacity of the soil. Findings of the present experiment did not show significant correlation of leaf-P and available soil phosphorus extracted by Bray and Kurtz No.1P method. The correlation between leaf-P in 14th frond and that in soils of the manure circle was negative($r = -0.11$, $P>0.05$).

Poor correlation between soil and leaf data for these sites implies that the soil data do not account for the leaf-P of the coconut palm. Also this is not a satisfactory measure of phosphorus availability to other tree crops.

## CONCLUSIONS

The results of the study revealed that two major soil series in Gampaha District were generally sufficient in available phosphorus for healthy growth of coconut. The higher levels of leaf-P in the palms than the critical leaf-P, where fertilizer applied annually, confirmed sufficient phosphorus in the soils. The lack of correlation between leaf phosphorus and available soil phosphorus extracted by Bray and Kurtz No.1P method showed that the Bray and Kurtz No.1 extractable phosphorus was not a suitable indice of phosphorus availability.

For the present trend of intercropping in coconut lands, sufficiency of available phosphorus in soil in fertilizer applied coconut lands demands more detailed studies to investigate the critical soil phosphorus values for coconut in these two major soil series-Boralu and Pallama in Gampaha District in Sri Lanka.

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